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(June, 1957)

EVAPORATION AND POTENTIAL EVAPO-TRANSPIRATION OVER THE INDIAN SUB-CONTINENT

By L. A. Ramdas

[Received for publication on June 8, 1956
Accepted for publication on June 11, 1956]
(With 5 Text Figs.)

THE object of this article is to discuss briefly the spatial distribution of (*a*) the mean annual evaporation and (*b*) the mean annual potential evapo-transpiration over the sub-continent of India, on the basis of our present available knowledge of these factors. Potential evapo-transpiration may be estimated according to a new simple technique developed by the author. A comparison of the chart for India so prepared shows significant departures from a chart recently published by Thornthwaite and co-workers[6].

Computed and actual evaporation data for India

(a) *Computed data*

Towards the end of 1932, soon after the author started work on Agricultural Meteorology in India, a review of the evaporation data then available presented almost complete lack of information regarding this element, which so largely controls the water supply in reservoirs as well as the water losses due to evaporation and transpiration from growing plants.

At the suggestion of the author, Raman and Satakopan[2], both of whom were then working in the Agricultural Meteorology Division at Poona, took up the problem of computing the evaporating power of the air layers near the ground, on the basis of the close relation which exists between evaporation and the relevant climatic factors. There are many theoretical and empirical formulae proposed by different workers for computing the mean daily evaporation from a water surface, freely exposed to the atmosphere. A number of these formulae are listed in the paper by Raman and Satakopan. It will be clear that evaporation is essentially a physical phenomenon controlled mainly by (*a*) the gradient of vapour pressure very close to the evaporating water surface and (*b*) the velocity of the air flowing over the water surface. The factor (*a*) defines the saturation deficit of the air layers moving over the water surface and is usually represented by (^{e}s—^{e}d), where ^{e}s is the saturation vapour pressure at the temperature of the water surface and ^{e}d is the actual vapour pressure in the air sample before it moves over the evaporating water surface.

One of the most satisfactory of these formulae, based on very exhaustive observations both in the laboratory as well as out in the open, and tested against the actual observations made at a network of stations in the U.S.A. with the standard

U.S.A. evaporimeter (4 ft. diameter tank, kept on a wooden support, with its water surface, one foot above the general level of the ground), proposed by C. Rowher is given below :

$$E=(1{\cdot}465-0{\cdot}0186\,B)(0{\cdot}44+0{\cdot}118\,W)({}^{e}s-{}^{e}d) \qquad (1)$$

Here, E=mean daily evaporation in inches during 24 hours ;

W=mean daily wind velocity at the level of the evaporating water surface ;

${}^{e}s$=vapour pressure in inches of mercury, at the mean daily value of the water surface temperature ;

${}^{e}d$=mean daily value of the vapour pressure in inches of mercury of the air flowing over the evaporating water surface (equal to the saturation vapour pressure at its dew-point) ; and

B=the mean daily value of the barometric pressure, in inches of mercury.

In adapting Rowher's formula for the calculation of evaporation at a network of stations in India, Raman and Satakopan had to take into consideration certain limitations in the available/normals of the climatological data of India. These have been fully discussed by them. The main points may be mentioned :

(i) The mean daily values of wind velocity are recorded at heights above ground that vary from station to station. They have been reduced to the level of 4 ft. (the height of base of the Standard Stevenson Screen), by using a curve of Chapman[9], giving the mean variation of wind velocity with height.

(ii) We have no data of water surface temperature. So the term $({}^{e}s-{}^{e}d)$ in Rowher's equation had to be approximated to $(\frac{100}{h}-1)\,e$, where 'h' is the relative humidity percentage and 'e' the vapour pressure of the air. This modified term actually represents the saturation deficit of the air at the level of the Stevenson Screen in which 'h' and 'e' are recorded.

The resulting modified formula used by Raman and Satakopan in their computations is :

$$E=(1{\cdot}465-0{\cdot}0186\,B)(0{\cdot}44+0{\cdot}118\,W)(\frac{100}{h}-1)e \ldots . (1)\text{-}a$$

It is well known that factors like air temperature, water surface temperature, relative humidity, wind velocity, etc. undergo large diurnal variations, particularly during the day-time under the influence of insolation. In fact, evaporation increases very rapidly after about 9 a.m. when convective turbulence and wind velocity begin to increase. The rate of evaporation, as well as the other factors referred to above, attain their maximum values in the afternoon about the epoch of maximum temperature[10]. Evaporation decreases rapidly towards the evening and is quite low or even negligible in seasons like winter, during the night. Again, air temperature varies rapidly with height in the layers near the ground. Nevertheless, it is satisfactory to note that, when we deal with the "mean daily values" of these factors, the diurnal ranges are suppressed and the variations with height tend to become relatively negligible.

In a formula which gives the "mean daily value" of evaporation based on the

"mean daily values" of the relevant meteorological factors, we are not likely to make any serious departure in our estimates of evaporation whether formula (1) or (1)-a is used. As the values so computed are essentially "climatological" estimates, one should expect that, even if the absolute magnitudes of these values may depend to some extent on which particular formula is used, the relative "spatial" variations or the general "pattern" of the evaporation chart over our sub-continent as a whole should be clearly brought out by the values computed from formula (1)-a. And it is only when one can compare these values with normals based on actual measurements made over a series of years that we may know how far we may have over or under-estimated in our computations.

From the results presented by Raman and Satakopan in their mean monthly evaporation charts, it is clear that the semi-arid tract to the east of the western Ghats, consisting of the Bombay, Deccan and adjoining tracts of the central parts of India, represent the area of maximum evaporating power of the air layers near the ground, during the dry season—November to May. When the south-west monsoon sets in June, the area of high evaporation shifts rapidly to north-west India, where the monsoon season is latest to set in and is brief in its duration. With the retreat of the monsoon, the area of high evaporation shifts back during October to November to the Bombay, Deccan and its neighbourhood.

Another feature is the less conspicuous centre of high evaporation in Madras south-east, during the south-west monsoon season, where the real rainy season sets in only during the north-east monsoon (autumn—winter period). The comparatively low evaporating power of the air near the ground in the relatively more humid and less windy areas of north-east India is also significant.

It is interesting to see the spatial variation of the mean annual evaporating power of the air layers near the ground as shown in Fig. 1. This diagram further emphasises the most important feature, viz., that the area of maximum annual evaporation is the Bombay, Deccan and adjoining areas to the east and north. The subsidiary maximum over the Tamilnad or Madras south-east is less conspicuous.

(*b*) *Actual evaporation records*

The charts showing the computed evaporation prepared by Raman and Satakopan on the basis of Rohwer's formula as modified in (1)-a have served a very useful purpose, as they gave us some reasonable estimates of the spatial distribution of evaporation over India when no actual observations were available. It is only very recently that we have been able to set up a network of about 40 stations equipped with U.S.A. type evaporimeters. This network is likely to intensify further in the near future. Of the existing stations, half are located at some of the regular weather reporting stations of the India Meteorological Department, while the remaining are at cropweather observatories of the Agricultural Meteorology Division, maintained by the various States of India. As usual, for the collection of reliable evaporation data also, many precautions are essential. Unnoticed leakage from the tanks, visitations by birds or animals to quench their thirst, are to be guarded against and reports of such vitiation of the data had indeed come from a few of the stations, particularly

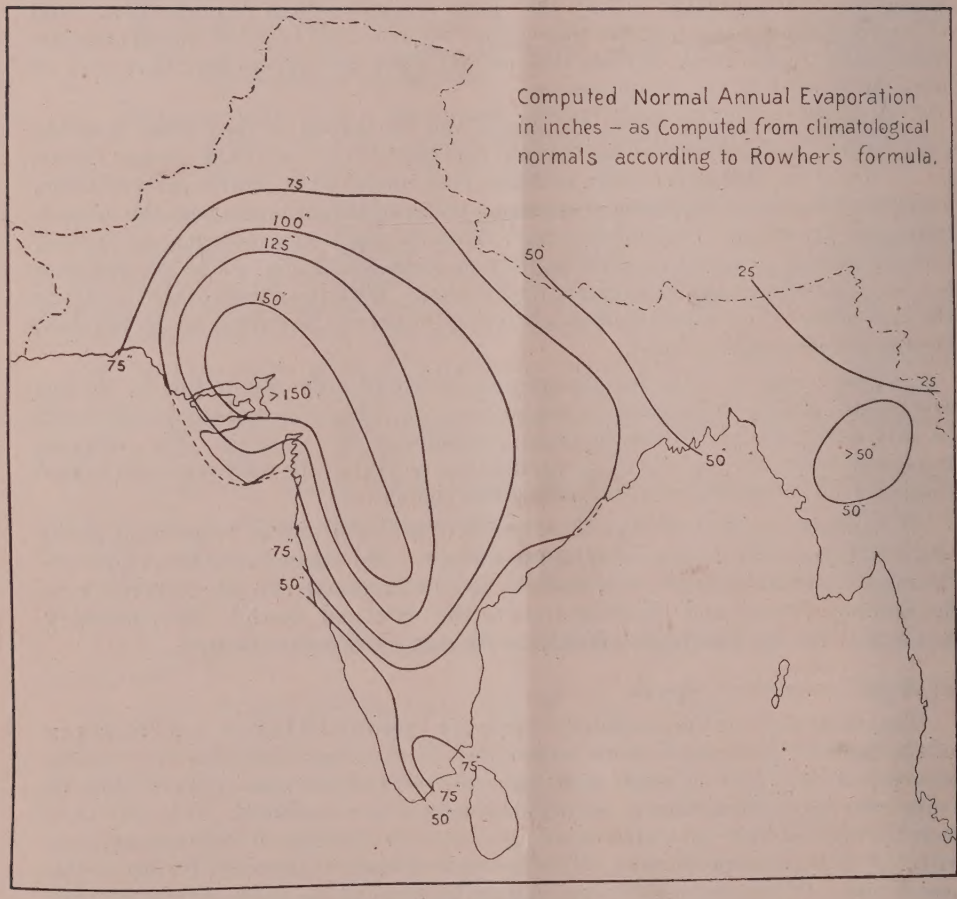
Computed Normal Annual Evaporation
in inches – as Computed from climatological
normals according to Rowher's formula.
75
100
125
150
>150
75
50
25
25
50
>50
50
75
50
75
75
50

FIG. 1

from the desert tracts of Rajasthan. Steps are being taken to overcome these sources of vitiation of the data. An examination of the data recorded during the last 2 or 3 years, both separately for each year and as the averages for the whole period of 2—3 years, clearly indicate, when charted on maps, that two or three stations show up obvious discordance with the data of stations in the neighbourhood. In drawing lines of iso-evaporation such discrepent data are ignored, as is generally done for example in drawing lines on weather charts. It is re-assuring to note that the charts for the individual years are more or less similar to the mean value charts.

It may be mentioned that the monthly evaporation values have been obtained from the data recorded only on "rainless" days. A comparison of the monthly values, based on "rainless" days only and the values as recorded since last year both on "rainless" and "rainy" days, shows that these monthly values do not differ materially, so that the values of evaporation for the year as a whole, based on "rainless" days alone, agree closely with the actual annual evaporation.

Fig. 2 shows the annual evaporation in inches, based on these data recorded during 1952-55. These average values are based only on 2 to 3 years' data and, therefore, are not strictly comparable to the estimates of the normal computed data presented in Fig. 1. A comparison of Fig. 1 and 2, does, however, clearly brings out the essential similarity of the spatial distribution of the annual evaporating power of the air layers near the ground, particularly with regard to the area of maximum evaporation over the Bombay, Deccan and neighbouring areas.

Having observed that Fig. 1 (computed data) is confirmed in its essential features by Fig. 2 (actual data), one is justified in utilising the computed values of Raman and Satakopan provisionally for a further consideration of some of the aspects of the moisture problem in relation to growing crops. When actual evaporation data become available for a longer term of years, one should naturally prefer these to computed values.

How to estimate "natural evaporation" or "potential evapo-transpiration" from an extensive wet area, from evaporation recorded from a standard U.S.A. type evaporimeter

In this section we shall discuss the results of some relevant experiments conducted at the Central Agricultural Meteorological Observatory at Poona. The U. S. A. Standard Evaporimeter referred to earlier is a land pan 4 ft. in diameter, 10 in. in depth, with the free surface of water 2 in. below the rim. The pan is supported on a wooden platform 4 in. in height so that, in effect, the free surface of water is just 1 foot above the level of the ground. This arrangement of the evaporimeter ensures that continuity in the records of evaporation is maintained even during unusually wet weather when a pan kept flush with the ground may be submerged under rain water. It is, however, important to note that evaporation from the water surface so elevated —1 foot above ground—will be affected by the increased wind velocity at that level.

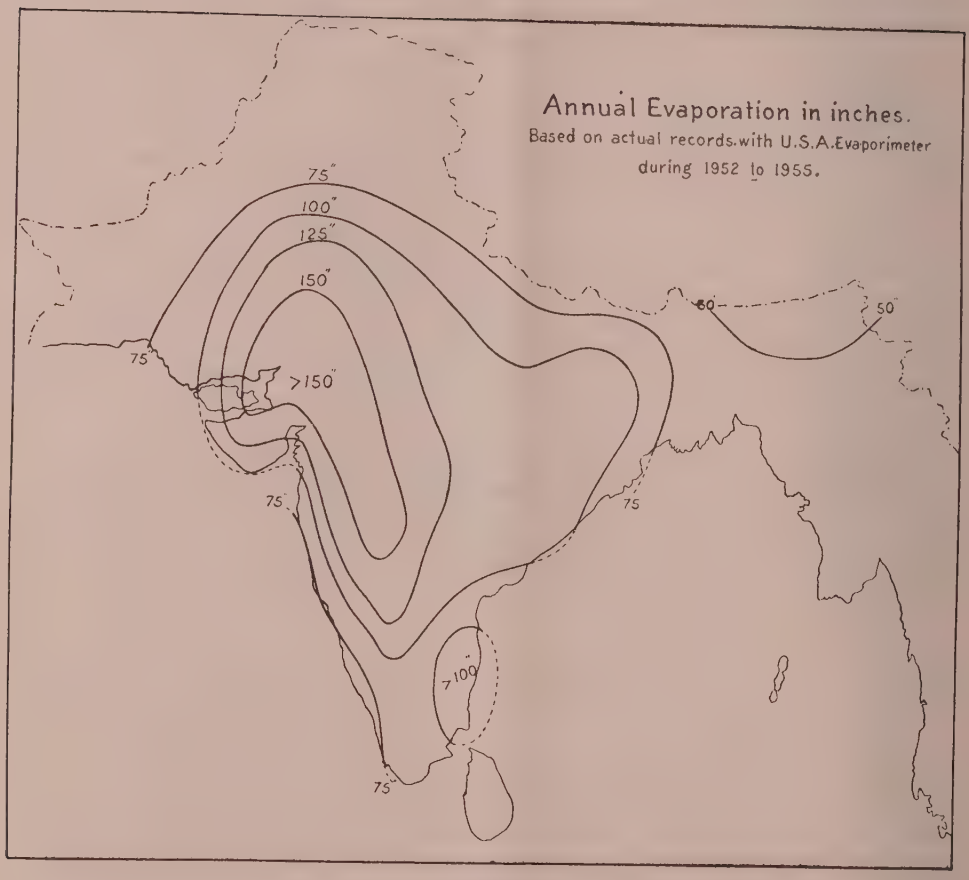
Annual Evaporation in inches.
Based on actual records with U.S.A. Evaporimeter
during 1952 to 1955.
75"
100"
125"
150"
>150"
>100"
75"
50"
75"
75"
75"
75"

FIG. 2

To arrive at a conversion factor to reduce evaporation from the standard instrument under normal exposure (1 foot above ground) to that from a similar water surface kept flush with the ground, a second instrument of the same type was installed at the Central Agricultural Meteorological Observatory and comparative observations recorded during a few years. If E is the evaporation from the instrument normally exposed with the water surface 1 ft. above ground and E_0 the evaporation from an exactly similar surface kept flush with the ground, then from this series of comparative observations it is found that :—

$$E_0 = \cdot 845\ E \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The conversion factor of ·845 is the average value obtained from the comparative observations recorded during the dry season for a number of years.

The value of E_0 represents the evaporation from an isolated water surface 4 ft. in diameter, kept flush with the general level of the surrounding bare ground. This value will be equal to the "natural" evaporation from an extensive area only when the ground surrounding the water surface is also completely wet or saturated with water. This will be the case only during rainy weather or when the surrounding area is heavily irrigated with water. Under such conditions equation (2) itself will give the "natural" evaporation.

When, however, the surrounding land is dry, the values of E_0 will need a further reduction. This further reduction factor has been arrived at by the following experiments conducted at the Central Agricultural Meteorological Observatory at Poona. A number of similar evaporimeters was installed with the water surfaces flush with the ground. They were surrounded each with a ring of wet soil, the width R of the wet ring varying from 4 ft. to 20 ft. respectively. One instrument was kept without the wet ring. The comparative observations recorded with this set of instruments showed clearly that the ratio E_{oR}/E_0 of the evaporation is 1·0 when R=0 but decreases rapidly with R, attaining a limiting value of the order of 0·70 when R has a large value. Using this value as the conversion factor, we have :

$$E_{oR\infty} = 0{\cdot}70 \times 0{\cdot}845 \times E = \text{approximately } 0{\cdot}60\ E \qquad . \quad . \quad . \quad . \quad (3)$$

Thus, during clear weather when the ground surrounding the evaporimeter is dry, $E_{oR\infty}$ the natural evaporation from an extensive wet ground or a lake may be computed from the observed value of E. When the surrounding area is already wet with rain or irrigation, E_0 itself as estimated under such conditions becomes equal to $E_{oR\infty}$.

By using the simple relations given by equations (2) and (3) we may estimate approximately the evaporation from extensive areas of wet soil saturated with water. This estimate of evaporation in a given month for any particular station will be

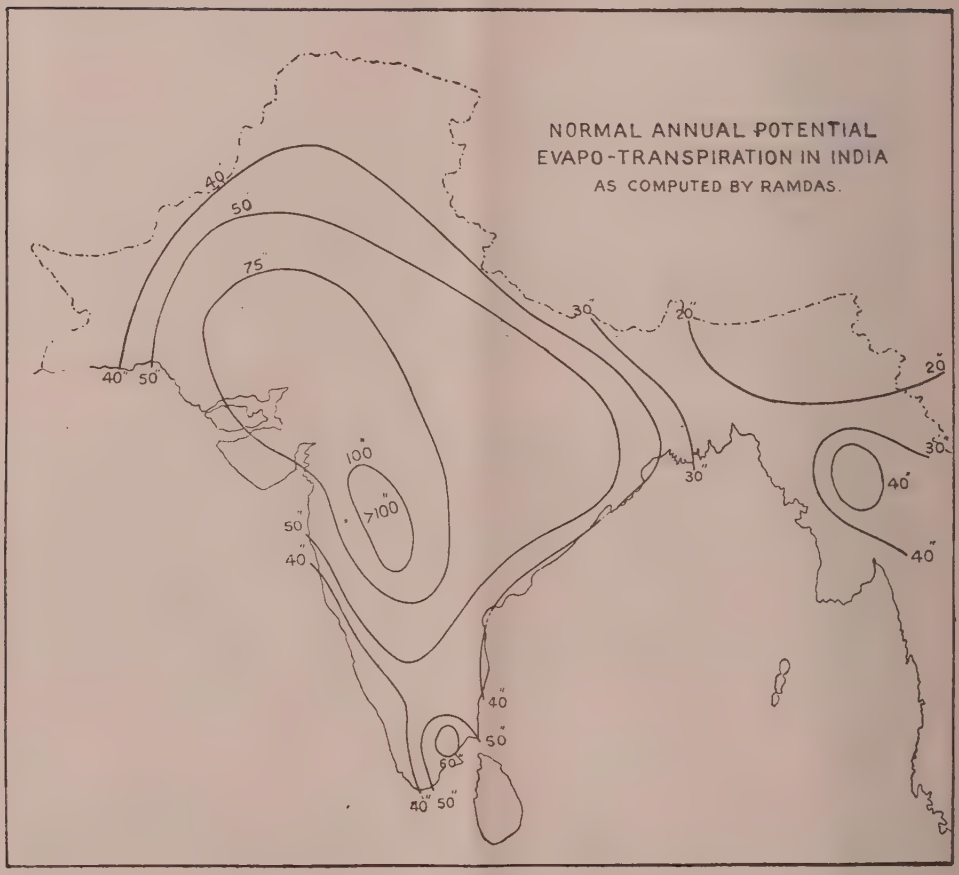
NORMAL ANNUAL POTENTIAL
EVAPO-TRANSPIRATION IN INDIA
AS COMPUTED BY RAMDAS.
40"
50"
75"
100"
>100"
30"
20"
60"

FIG. 3

obtained by using relation (2) for rainy days and (3) for dry days. The quantity so estimated is not likely to differ significantly or largely from the loss of moisture by evaporation and transpiration combined from a similar area covered with vegetation. This is indicated by recent preliminary experiments conducted at Poona from bare soils in pots saturated with water and similar soils with growing plants. We may, therefore, provisionally call the natural evaporation from ground saturated with water, as approximating to "potential evapo-transpiration", to use the terminology of Thornthwaite.

Values of $E_{oR\infty}$ representing what the evaporation is likely to be from an extensive lake or from an extensive area of wet or water-logged land or from a cropped area at full irrigation, have been computed for each month of the year, using provisionally the computed values of E given by Raman and Satakopan. The annual values of potential evapo-transpiration (P.E.T.) so obtained are shown in Fig. 3 and these are naturally much lower than the evaporation values shown in Figs. 1 and 2; but the general pattern of "P.E.T." preserves, as is to be expected from the climatological pattern, the same general features, viz. a centre of high potential evapo-transpiration in the Deccan, with rapidly decreasing values as one moves away in different directions therefrom; the secondary high over Tamilnad is also brought out.

We may now proceed to compare our values shown in Fig. 3 with those in Fig. 4 which represents the distribution of mean annual potential evapo-transpiration as computed in Dr C. W. Thornthwaite's Laboratory of Climatology, Johns Hopkins University, New Jersey, by V.P. Subramanyam. These values were supplied to the author through the courtesy of the above institution. The techniques followed in these computations have been discussed in detail by Thornthwaite [3, 4, 5] in a series of papers which may be referred to. A comparison of Figs. 3 and 4 shows that, while the pattern shown by Fig. 3 is generally consistent with those shown by Figs. 1 and 2, Fig. 4 shows an entirely different pattern of "P.E.T.", differing in the essential features in a very marked manner. Thus in place of the centre of high "P.E.T." in the Bombay Deccan we have an area of low values: the area of highest "P.E.T." in Fig. 4 appears over the eastern coast of the Peninsula. These features are not consistent with the features regarding the evaporating power of the air layers near the ground revealed by Figs. 1 and 2 or the estimates of P.E.T. shown by the present author in Fig. 3.

In Fig. 5 is shown a more recent or revised map of potential evapo-transpiration which has been reproduced from a recent publication by Douglas B. Carte [6]. Here again, we have the same difficulty in accepting the general features which do not fit in with pattern revealed by Fig. 3.


NORMAL ANNUAL POTENTIAL
EVAPO-TRANSPIRATION IN INDIA
AS COMPUTED BY V.P.SUBRAMANYAM
(THORNTHWAITE'S LABORATORY)
40"
50"
40"
50"
60"
60"
60"
60"
50"
<50"
70"
>70"
70"
>70"

FIG. 4

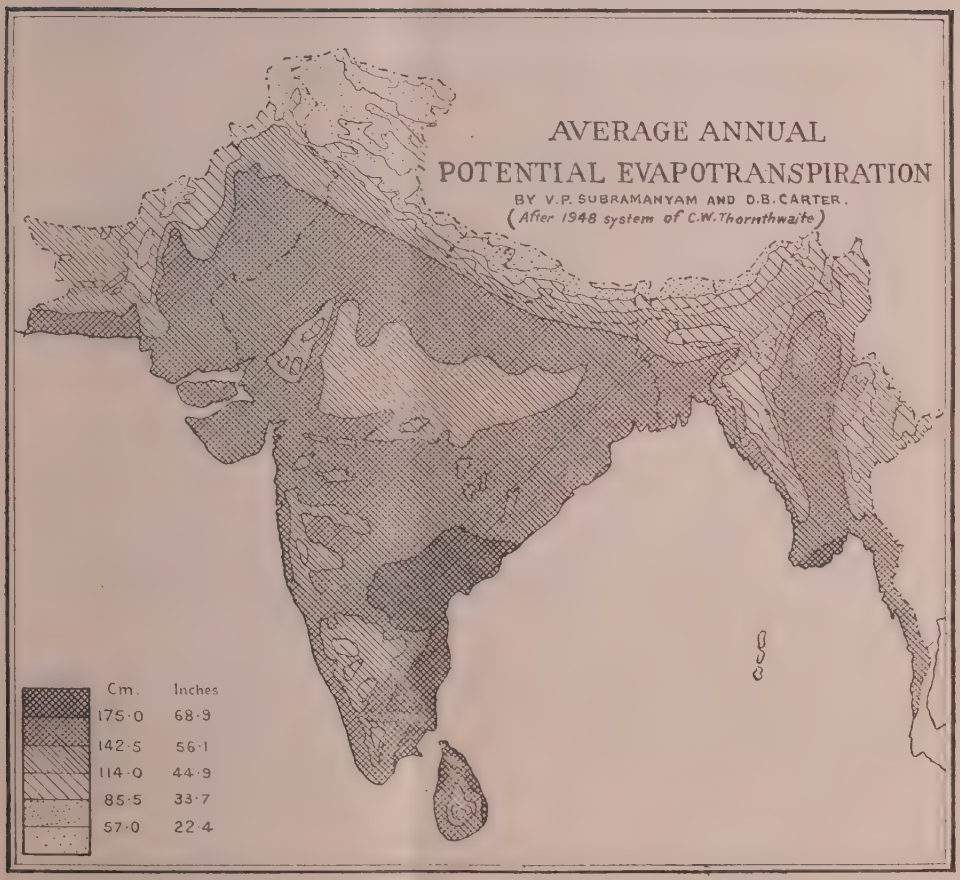
AVERAGE ANNUAL
POTENTIAL EVAPOTRANSPIRATION
BY V.P. SUBRAMANYAM AND D.B. CARTER.
(After 1948 system of C.W. Thornthwaite)
Cm. Inches
175·0 68·9
142·5 56·1
114·0 44·9
85·5 33·7
57·0 22·4

FIG. 5

Actual potential evapo-transpiration is soon likely to be recorded at a network of selected stations in India and when these become available, we shall be able to confirm experimentally how far the pattern shown by Fig. 3 fits in with observed facts.

Effect of depth of free water table or zone of saturation in the sub-soil on the rate of evaporation from the top of the soil surface

The results of these experiments have been discussed elsewhere [7, 8]. Using a series of soil evaporimeters with different depths of similarly packed soil layers ranging from 6 in. to 3 ft., all exposed so that the evaporating top surfaces are at the same level while the free water table in the reservoirs below are at different distances from the soil surfaces, it has been found that the rate of evaporation Ez when the distance between the water table or zone of saturation and the surface is z cm., decreases very rapidly as z increases. The relation between Ez and E_0 where E_0 is the evaporation from the soil surface when the water table is at the soil surface itself, is given by :

$$E_z = E_0 \times 10^{-\infty z} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where ∞ is a constant characteristic of the soil. Thus, if we know the value of E_0R∞ when an extensive area of bare soil is saturated with water and wish to estimate Ez in an similar neighbouring area where the water table or zone of saturation is z cm. below the soil surface (this can be easily ascertained by digging an experimental pit), this may be computed from the above relation.

Methods of estimating the actual evapo-transpiration, "E.T.", from crop-growing areas with unsaturated surface soil and with the zone of saturation some distance below, are under investigation at Poona.

Conclusion

The author thanks the Indian Council of Agricultural Research for sustained interest in these investigations and for recently sanctioning a scheme for developing experimental techniques for the estimation of the water requirements of crops. He is grateful to Dr C. W. Thornthwaite for arranging to send an advance copy of V. P. Subramanyam's computations presented in Fig. 4. He also thanks to Shri S. P. Venkiteshwaran, the present Director of Agricultural Meteorology and to the staff and research fellows engaged in these researches for their collaboration. Shri T. S. Govindaswamy and Shri H. R. Ganesan have rendered valuable help in the computation of the data presented in Figs. 2 and 3 respectively.

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EFFECT OF SPACING ON DEVELOPMENT AND YIELD OF ARUM (*COLOCASIA ESCULENTA*)

By S. S. Purewal and Karam Singh Dargan, Government Agricultural College, Ludhiana, Punjab

[Received for publication on May 16, 1956]
[Accepted for publication on October 29, 1956]

COLOCASIA ESCULENTA (arvi) is primarily a crop of warm, humid, marshy regions. It grows on all kinds of soils, but thrives best in deep, well manured, and friable loams. In dry regions, it is cultivated under irrigation.

Its yields vary considerably according to the variety and the cultural practices adopted. Introduction of improved varieties will go a long way to increase the crop yields but maximum yields can only be obtained when improved varieties are grown under the best cultural practices such as spacing, manuring and watering, etc. The spacing of *Colocasia* plant, directly or indirectly through the amount of plant food available, influences the yield greatly. The spacings have also to be altered in accordance with the time the crop has to stand in the field ; consequently various spacings from 1½ sq. ft. to 12 sq. ft. per plant have been recommended by different workers. In Hawaian Islands where the crop remains in the field for a longer period, i.e. 8 to 16 months, wide spacing is practised while in India where the duration of this crop is from four to eight months, comparatively close spacing is employed.

Mollison [1901] remarked that for sowing *Colocasia* the field should be laid into beds 12 ft. × 6 ft. for irrigation, there being 40 plants in each bed. However, if it be grown for its corns, the plants should be 12 in. apart.

According to Kidava [1915] for a wet land crop, germinated tubers are planted in circular pits, more than a foot in diameter and 9 in. deep, having a distance of three feet from centre of one pit to the other. The pits are made on raised beds. Young [1916] says that in rich soil the crop requires about 12 sq. ft. per plant, the space being 4 ft. × 3 ft. or 3½ ft. × 3½ ft. The same author [1936] recommends 3½ ft. to 4 ft. row to row spacing and 2 ft. plant to plant spacing. Dhanna Lal [1937] recommended that for *Colocasia* row to row spacing should be 2 ft. and plant to plant in the rows 9 in. The sowing should be done in the middle of furrow 3 in. to 4 in. deep. Sanka Ram [1943] recommended 1½ sq. ft. spacing per plant. Purewal [1944] states that sets about 2 oz. and possessing 2-3 eye buds each are sown 3 in. deep and 8 in. apart on ridges about 9 in. high and 2 ft. to 2½ ft. apart. Chaudhri [1947] mentioned that distance between the ridges should be 1½ ft. and between plants 1 ft.

Experimental

To ascertain the optimum spacing of this crop under the Punjab conditions, the present investigations were carried out under the 'Research Scheme on Tuber crops' financed jointly by the Indian Council of Agricultural Research, New Delhi and the Punjab Government. The experiments were conducted at Agricultural Station, Jullundur, during the year 1950 and 1951. During the growing period (March-October), rainfall of 49·25 inches was received in the year 1950 and 17·40 inches in 1951, the latter year being comparatively hot and dry. In 1950, the crop was produced in a loam soil of good fertility while in 1951, it was produced in sandy loam soil of comparatively low fertility.

Seed tubers of *Colocasia* were obtained from Ludhiana. A famous variety locally named as '*Did Arbi*' best suited for the plains and quite uniform was selected. This variety had tall, vigorous and erect plants with dark green petioles generally lacking anthocyanin. The corms had round shape, brownish skin colour with white and soft flesh and bearing numerous rhizomes that are compact around the corm. Primary rhizomes are many with numerous secondary and tertiary tubers which are light brown in colour with smooth skin and white flesh. The tubers are of uniform shape and size with thin unions that can be shaken off easily.

Basic dose of F. Y. M. was applied at the rate of 20 tons per acre. Then the field was thoroughly prepared by giving four ploughings and two draggings. The crop was sown on the 24th February, during both the years. In all, the crop was hoed six times and earthed up twice, first in the end of June and then during the middle of August. No fertilizer was applied during the year 1950, as the field was sufficiently rich, but during the year 1951, the field being poor, the trial was given 40 lb. N_2 per acre from ammonium sulphate. The crop was harvested on the 7th October, 1950 and on the 18th October, 1951.

Three row spacings of 1½ ft., 2 ft. and 2½ ft. were tried together with three plant spacings of 6 in., 9 in. and 12 in. The layout plan of the experiment was factorial design, randomised blocks, with four replications, the size of the net plot being 1/198 acre. The experiment received 21 irrigations during 1950 and 26 irrigations during 1951. During 1950 the crop was attacked by mites, which were controlled by spraying with lime sulphur. During 1951, the crop was badly attacked by *Phytophthora colocasiae* Rac. which appeared at the critical time of tuber development resulting in rather poor yield due to the stopping of the growth of the plants after the middle of August.

Characters studied and sampling technique

Observations on the following characters were recorded :

(i) *Germination :* The germination counts were recorded by counting all the plants in all the replications.

The following other observations were recorded only on 12 randomly selected and marked plants in each replication,

(ii) *Height.* For measuring the progressive increase in height, measurements were recorded in centimeters at two weeks interval and were continued till there was no further increase in height.

(iii) *Leaf area.* For recording leaf area, the largest leaf of the plant was selected and its area was measured by placing it against a glass slab marked in square centimeters. These observations were recorded at four weeks' intervals.

(iv) *Number of tubers per plant.* Tubers harvested from each plant under observation were counted separately.

(v) *Yield per plant.* Weights of tubers and corms of each selected and marked plant were recorded separately in ounces.

(vi) *Yield per acre.* Total yield per acre was worked out by adding the weight of corms and rhizomes harvested from the individual plots.

Results

The results of the investigations carried out are briefly reported as under :

(i) *Germination.* The various spacings between rows and plants had no effect on the germination percentage during the two years as would be evident from the Table I.

Table I

Percentage germination under main effects

Particulars of the treatments	Germination percentage	
	1950	1951
R1—1½ ft. spacing between rows	91·1	98·0
R2—2 ft. spacing between rows	93·6	99·0
R3—2½ ft. spacing between rows	93·1	99·1
P1—6 in. spacing between plants	90·2	98·7
P2—9 in. spacing between plants	92·3	98·7
P3—12 in. spacing between plants	95·4	98·6
C. D. at 5 per cent	7·8	1·19
Rows spacings	R2, R3, R1	R3, R2, R1
Plant spacings	P3, P2, P1	P1, P2, P3,

(ii) *Height.* Table II shows the comparative rate of increase in height of plant due to main factors.

TABLE II

Rate of increase in height per plant (in centimeters)

Dates of observation	R 1½ ft.	R 2 ft.	R 2½ ft.	P1 6 in.	P2 9 in.	P3 12 in.
			1950			
27/4	10·2	8·8	8·8	9·8	9·5	9·6
11/5	17·1	14·6	16·7	16·3	15·9	17·3
25/5	23·0	19·4	21·7	21·4	20·8	21·9
8/6	31·4	26·2	29·5	29·3	27·8	30·0
22/6	37·1	31·8	35·4	34·5	34·2	39·0
6/7	43·0	37·9	41·3	40·0	40·7	42·0
20/7	59·9	56·5	60·2	56·9	58·1	61·6
3/8	68·5	67·4	70·4	65·9	67·5	72·8
17/8	75·3	77·1	78·6	72·5	76·4	82·2
1/9	78·3	80·6	81·8	75·8	79·0	86·0
15/9 (Max. Ht.)	79·04	82·72	83·57	77·09	81·39	86·36
			1951			
27/4	8·8	8·8	9·1	8·8	8·6	9·3
11/5	12·7	12·9	13·5	13·0	12·6	13·4
25/5	17·6	18·1	19·6	17·7	18·3	19·4
8/6	22·8	24·4	26·8	22·4	24·5	27·6
22/6	26·0	27·3	29·8	25·5	27·6	29·9
6/7	33·2	34·5	36·1	32·4	34·5	36·9
20/7	41·4	43·2	44·1	39·9	42·9	45·0
3/8	47·7	50·9	51·5	46·8	49·5	53·8
17/8 (Max. Ht.)	50·03	52·47	54·23	48·87	51·77	56·13

Summary of results for final height :

	1950	1951
C. D. at 5 per cent	6·17	2·47
Rows spacings	R3, R2, R1	R3, R2, R1
Plant spacings	P3, P2, P1	P3, P2, P1

In 1950, in the early stages, the rate of increase of plant height was practically uniform in all the treatments and the difference in height due to wide and close spacings between rows and plants was small ; but in the later stages widely spaced plants showed greater height than closely spaced ones. In all the treatments, maximum increase in height was observed from 6/7 to 20/7.

In the year 1951, throughout the growing period the increase in height was slightly more in wide spacings than that under close spacings of rows and plants.

Final height was more under wide spacings than under close spacings during both the years. In the first year the differences in height due to row spacings were non-significant, while 12 in. spacing between plants increased the height significantly over 6 in. spacing. In the second year $2\frac{1}{2}$ ft. spacing between rows increased the height significantly over $1\frac{1}{2}$ ft. spacing. The wide plant spacings were also significant on successive close plant spacings. The two factors studied together did not interact significantly. In 1951, too, the maximum increase in height in all the treatments was observed from 6/7 to 20/7.

Dastur and Gopani [1952] made similar observations in the cotton crop. Frank Crowther [1936] also found that wide spacings produced taller plants in wheat and cotton crops.

Leaf area. As the growth proceeds, the older leaves dry up and slowly fall off and the new leaves arise in their axils. The successive leaves are larger in size until the maximum height of the plant is attained. It was observed that average number of leaves per plant varied from 1 to 2 in the middle of April ; from 3 to 4 in the beginning of July and 4 to 5 in the end of September. Table III shows the sizes of leaves formed at various stages of growth.

TABLE III

Rate of increase of leaf area in square centimeters

Main factors	Dates of observations					
	2/5	30/5	27/6	25/7	22/8	19/9 (Final)
			1950			
R1	61·6	166·8	272·8	631·0	707·3	712·17
R2	75·5	190·2	319·0	696·7	743·6	746·33
R3	75·7	214·5	356·5	689·5	764·8	766·92
P1	63·4	163·7	272·4	598·2	667·9	672·33
P2	73·0	196·4	324·2	688·9	760·2	760·42
P3	76·8	211·5	348·7	730·1	788·0	790·67
			1951			
R1	86·2	175·9	225·2	421·9	453·46	
R2	88·5	180·3	272·0	466·5	475·10	
R3	91·5	198·1	296·6	450·5	484·36	
P1	87·9	173·0	247·0	411·0	447·13	
P2	86·0	182·7	277·7	439·6	469·07	
P3	92·2	198·6	299·0	468·1	496·73	

Summary of results :	1950	1951
C. D. at 5 per cent	74·92	15·33
Row spacings	R3, R2, R1	R3, R2, R1
Plant spacings	P3, P2, P1	P3, P2, P1

Table III shows that wide spacings produced larger leaves than close spacings practically at all stages of growth during the two years. In all the treatments the maximum growth was observed from 27/6 to 25/7 during both the years.

Although wide spacing between rows produced bigger leaves than the close spacings but the differences were non-significant during the first year. In the second year, however, 2½ ft. and 2 ft. spacings produced significantly larger leaves

than 1½ ft. spacing. As regards plant spacings, the leaf area increased significantly due to 12 in. and 9 in. spacings over 6 in. spacing during the first year while in the second year the leaf area increased significantly as the spacings between plants were increased from 6 in. to 9 in. and 9 in. to 12 in.

The two factors, viz. spacings between rows and plants did not interact significantly.

Number of tubers per plant. Wide spacings between rows and plants increased the number of tubers significantly over close spacings during the two years as is evident from Table IV. However, no inter-action of rows and plants was observed.

TABLE IV

Mean number of tubers per plant due to main factors

Main effects	Mean number		Remarks	
	1950	1951	1950	1951
R1	24·30	9·7	C.D.=3·38	C.D.=1·02
R2	29·01	10·5		
R3	33·40	11·1		
			R3> R2> R1	R3, R2, R1
P1	24·81	9·6		
P2	28·85	10·4	P3> P2> P1	P3, P2, P1
P3	33·05	11·45		

The greater number of tubers under wider spacings was perhaps due to the secondary growth of branches which were more under wide spacing than under close spacings. These branches also produced some tubers independently of the main plant which evidently led to the increase in the number of tubers under wide spacings.

Yield per plant. The 2½ ft. and 2 ft. spacings between the rows increased the yield per plant significantly over 1½ ft. spacing between the rows in both the years. Similarly 12 in. and 9 in. spacing between the plants increased the yield significantly over 6 in. spacing between the plants during the two years. The data are summarised in Table V.

TABLE V

Mean yield per plant due to the main factors

Main factors	Main yield in oz.		Remarks	
	1950	1951	1950	1951
R1	13·80	2·99	R3, R2, R1	R3, R2, R1
R2	17·26	3·61	P3, P2, P1	P3, P2, P1
R3	19·98	3·71	C.D. at 5 per cent=2·64	0·58
P1	14·93	2·33		
P2	17·60	3·71	R×P	R×P
P3	18·98	4·28	C.D. at 5 per cent=4·08	1·01

During the first year inter-action between rows and plants, spacing was also observed but during the second year spacings between rows and plants did not inter-act significantly. The highest yield per plant was obtained in the combination 2½ ft. × 12 in. during the two years.

Frank Crowther [1936] also observed that yield per plant was more with wider spacing in the case of cotton.

Yield per acre. The superiority of one treatment over the other is to be judged solely by the over-all yield obtained from it. Other considerations apart, the yield per acre is the best criterion for judging the merits of any practice, because ultimately it is the yield per unit area which determines the suitability or otherwise of a treatment. Table VI shows yields per acre in maunds for each treatment.

TABLE VI

Yield per acre in maunds (one maund=82 lbs.)

Row to row spacing	Plant to plant spacing			Mean for rows
	6 in.	9 in.	12 in.	
		1950		
1½ ft.	274·72	241·38	268·92	261·63
2 ft.	264·90	268·30	247·11	260·10
2½ ft.	246·26	235·74	209·30	230·43
Mean for plant spacings	261·96	248·47	241·77	
		1951		
1½ ft.	62·34	64·04	72·58	66·3
2 ft.	65·59	71·40	61·87	66·3
2½ ft.	57·54	53·98	47·02	53·0
Mean for plant spacings	63·14	61·82	60·49	

Summary of the results :

	1950	1951
1. Row spacings	R1, R2, R3	R1, R2, R3
2. Plant spacings	P1, P2, P3	P2, P1, P3
3. C. D. at 5 per cent due to R. and P.	17·39	3·88
4. Inter-action for rows and plants	R×P	R×P
5. C. D. at 5 per cent due to inter-action	31·72	6·64

There was no significant difference of yield between $1\frac{1}{2}$ and 2 ft. spacings between rows, but both of them yielded significantly higher than $2\frac{1}{2}$ ft. spacing. As regards spacing between plants, 6 in. spacing yielded significantly higher than 12 in. spacing at 5 per cent level during the first year only, while in the second year the differences of yield of all plant spacings were non-significant. No inter-action of row spacings and plant spacings was observed during 1950, while during 1951, various spacings between rows and plants inter-acted significantly. During 1950, the highest yield was obtained with combination $1\frac{1}{2}$ ft. $\times$ 6 in. followed by $1\frac{1}{2}$ ft. $\times$12 in. and 2 ft. $\times$9 in. combinations respectively. In 1951, however, combination $1\frac{1}{2}$ ft. $\times$ 12 in. yielded the highest and this was followed by combination of 2 ft. $\times$ 9 in. and 2 ft. $\times$ 6 in. respectively.

Although yield per plant was more in wide spacing than in close spacing but the total yield was more under close spacing than under wide spacings.

Frank Crowther [1936] in wheat crop and Gupta [1952, unpublished] in potato crop also found that total yields were more under close spacing than under wide spacing because spacing affects the yield by its influence in controlling the density of population of plants. The relative yield per plant is more under wide spacing but the added increase in yield is too small to compensate for the decrease in the number of plants. The yield per acre, therefore, falls down in wide spacings.

Important correlations

Complete correlation coefficients. Data with regard to average total height per plant and mean leaf area per leaf for the marked plants was used to find out the correlations with the mean weight of tubers per plant. The results obtained are as under :

Correlation between	Calculated 'r'	
	1950	1951
Total height and plant yield	·81**	·92**
Final leaf area $\times$ plant yield	·79**	·907**
Total height $\times$ final leaf area	·89**	·98**

It is evident that all these correlations are positive and are very high which shows that yield is highly correlated with height and leaf area and that there is great association between leaf area and height.

Partial correlation coefficients

Partial correlations were worked out to correlate each of the two factors, namely, height and leaf area with yield by keeping one of the two constants. The results obtained are as under :

	1950	1951
Correlation between plant yield and plant height, keeping leaf area constant	0·38	0·49
Correlation between plant yield and leaf area, keeping height constant	0·26	0·08

The results are non-significant, meaning thereby that plant height and leaf area independent of each other do not influence the plant yield to a significant extent. As the plant height and leaf area have exhibited a very close association between themselves, it may be inferred that the combined effect of these factors on yield is a marked one.

Economic aspect of the trial

The ultimate benefit to the growers is the net return per unit area after deducting the extra cost on seed, etc. Study of economic aspect aims at finding the optimum spacing between rows and plants, where maximum profitable returns can be obtained. The value of produce and cost of seed were calculated at Rs. 5 and Rs. 10 per maund respectively which were the average market rates for 1950 and 1951. Income received from various treatments after deducting the cost of seed has been given in Table VII. However, the cost of extra labour required for harvesting closer spacings have not been included, because in Jullundur area where these experiments were conducted, the harvesting is usually done on contract basis at flat rates of Rs. 90 to Rs. 100 per acre. Therefore, it will not make much difference if the cost of harvesting of each treatment is calculated separately.

TABLE VII

Price of produce minus cost of seed in rupees

Row to Row spacing	Plant spacings					
	1950			1951		
	6 in.	9 in.	12 in.	6 in.	9 in.	12 in.
1½ft.	1133·6	1049·9	1224·6	71·7	160·2	242·9
2ft.	1144·5	1221·5	1145·5	147·9	237·0	219·3
2½ft.	1087·3	1082·7	974·5	143·7	173·9	163·1

The study of Table VII shows that combination 1½ ft. × 12 in. gave the maximum income while combination 2 ft. × 9 in. was the second best during the two years. Therefore, it can safely be concluded that 1½ sq. ft. space per plant (1½ ft. × 12 in. or 2 ft. × 9 in.) is the optimum spacing for a *Colocasia* plant.

Conclusions

1. The different spacings between rows (1½ ft., 2 ft. and 2½ ft.) and from plant to plant (6 in., 9 in. and 12 in.) did not have any effect on germination.

2. The height and leaf area were more under wide spacing than under close spacing, both due to row and plant spacings.

3. The maximum increase in the height of the plant occurred from 6/7 to 3/8 but the maximum increase in the leaf area occurred from 27/6 to 25/7. The grand period of growth of the local type of *Colocasia* plant (Did Arvi) under punjab conditions seems to occur during the month of July.

4. Wide spacings between rows as well as plants gave greater yield per plant as compared to close spacing between rows and plants.

5. The number of tubers per plant was significantly more under wide spacings than under close spacing of rows and plants.

6. The one and a half and two feet spacing between rows, gave significantly higher yields than 2½ ft. spacing whereas the differences of yield due to various plant spacings of 6 in., 9 in. and 12 in. were found to be non-significant.

7. Highly significant and positive correlations exist between plant yield and plant height, plant yield and leaf area and between height and leaf area.

From partial correlations it appears that both these ancillary characters affect the yield jointly.

8. Spacing of 1½ ft. × 12 in. gave the most economical returns followed by 2ft.×9in. which was second best in order of merit.

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SEED RATE OF *HIBISCUS SABDARIFFA* L.

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OPTIMUM seed rate as a means of controlling ultimate population has an important bearing in the production of agricultural crops, especially the different bast fibre crops where the seed rate plays a very important role in determining the yield and quality of the produce. The seed rate, in general, depends upon (a) growth characteristics of the crop and variety, (b) purpose for which the crop is grown, (c) soil and climatic conditions, (d) method of sowing, (e) germination percentage, (f) mortality percentage, etc.

Hibiscus sabdariffa L. (Rosselle), a bast fibre plant belonging to the family Malvaceae has in recent years gained much importance as one of the good substitutes for jute. Ergle, Robinson and Dempsey [1945] in a comparative study with three malvaceous bast fibre crops namely, *Hibiscus cannabinus* L, *H. sabdariffa* var. *altissima* and *Urena lobata* L., obtained a maximum fibre yield of 2,791 lb. per acre in *H. sabdariffa* by using a seed rate of 60 lb. per acre. Crane [1949] while reviewing the work of Malaya, stated that a seed rate of 20-25 lb. per acre is recommended in this State for the line sowing of *H. sabdariffa* for drilling the seeds in rows three to six inches apart. Rama Rao [1950] recommended a seed rate of 8-10 lb. per acre for broadcast sowing of roselle in the Visakhapatnam district in India. Experiment conducted by the West Bengal Agricultural Department [1949-50 and 1950-51] at Chinsurah Farm with a view to find out the best seed rate for *H. sabdariffa* var. *altissima* did not show any significant difference in the fibre yield among the four different seed rates, namely, 10 lb., 20 lb., 30 lb. and 40 lb. per acre. As the seed rates recommended by the different workers vary in a wide range of 8 to 60 lb. per acre, investigations were undertaken to determine the optimum seed rates and their effect on the yield of fibre, plant height, base diameter, plant population and percentage of mortality.

Material and Methods

A seed rate experiment of *Hibiscus sabdariffa* L. R. T. 2, a type evolved at the Jute Agricultural Research Institute was conducted in different sites under indentical climatic conditions at the Jute Agricultural Research Institute, Barrackpore with eight different seed rates per acre starting from 5 lb. to 40 lb. per acre 5, 10, 15, 20, 25, 30, 35 and 40 lb., in randomized blocks with five replications. A basal dressing at the rate of 3 tons of compost per acre was applied each year before the sowing of the experiment. The seeds were sown broadcast.

The intercultural operations consisted of weeding and mulching and care was taken not to thin the plants. The crop was harvested at early-pod stage for the extraction of fibre.

The experiment was conducted for three years from 1952 to 1954.

Data on average plant height, average base diameter of plants (based on 20 plants for each treatment per replicate), plant population at harvest and fibre yield were recorded each year and the data were subjected to serial analyses. Mortality percentages of the plants in different seed rates were also estimated.

Fibre yield

The data on the yield of fibre per acre due to different seed rates during the three years have been given in Table I and the analysis of variance in Table II.

TABLE I

Fibre yield per acre in different seed rates

Layout : Replicated randomized blocks in 5 replications

Effective plot size : 22ft.×13ft.=·006567 acre = 1/152 acre (approximately)

Seed rate (per acre)	Mean yield of fibre per plot in lb.			Yield per plot in lb. (Av. of 3 years)	Average yield of fibre per acre in lb.
	1952	1953	1954		
5 lb.	15·95	14·39	11·48	13·94	2123·17
10 lb.	16·17	15·82	12·06	14·68	2235·88
15 lb.	15·21	15·17	12·54	14·31	2179·52
20 lb.	14·24	14·30	11·28	13·27	2021·12
25 lb.	13·88	14·32	10·89	13·03	1984·57
30 lb.	11·87	14·07	10·61	12·18	1855·11
35 lb.	12·14	12·34	10·13	11·54	1757·63
40 lb.	11·38	13·20	9·93	11·50	1751·54
P	·01	Large	·01	—	·01
C. D.	3·64	—	1·89	..	253·29
S. E. per cent	6·70	5·91	4·35	..	3·41

TABLE II

Analysis of variance of fibre yield

Source of variation	D. F.	S. S.	M. S.	F.
Year	2	228·61	114·305	38·165**
Block (within year)	12	23·13	..	..
Treatment	7	157·56	22·509	7·515**
Treatment × year	14	35·21	2·515	..
Error	84	251·56	2·995	..
Total	119	696·07	..	..

** Significant at 1 per cent level

C. D. at 1 per cent level = 253·29 lb./acre

S. E. per cent = 3·41

The effects due to year and treatment (seed rate) are both significant at 1 per cent level and the effect of first order interaction between treatments and years is not significant. From Table I it may be noted that 10 lb. of seed rate per acre has given the highest yield of fibre (2235·88 lb./acre) and it comes in the same group with other seed rates from 5 to 25 lb. per acre at 1 per cent level of significance.

A seed rate of 40 lb. per acre has given the lowest yield of fibre (1751·54 lb./acre) which is in the same group with seed rates of 25, 30, and 35 per acre at 1 per cent level.

Plant height

The data on the average plant height due to different seed rates for the three years and the analysis of variance are given in Table III and IV respectively.

TABLE III

Average plant height

Seed Rate (per acre)	Average plant height in feet			Plant height in ft. (average of 3 years)
	1952	1953	1954	
5 lb.	10·90	11·21	10·31	10·81
10 lb.	11·16	9·15	9·35	9·89
15 lb.	9·42	8·85	8·10	8·79
20 lb.	8·96	7·71	6·72	7·80
25 lb.	8·84	8·16	6·52	7·84
30 lb.	9·54	6·91	6·42	7·62
35 lb.	8·72	7·39	6·09	7·40
40 lb.	9·21	7·54	5·24	7·33
P	·01	·01	·01	·01
C. D.	1·52	1·63	2·26	1·01
S. E. per cent	4·04	4·99	7·87	3·23

TABLE IV

Analysis of variance of plant height

Source of variation	D. F.	S. S.	M. S.	F.
Year	2	101·36	50·680	45·494**
Block (within year)	12	14·89	..	..
Treatment	7	173·82	24·831	22·290**
Treatment × year	14	29·24	2·089	1·875
Error	84	93·55	1·114	..
Total	119	412·86	..	..

** Significant at 1 per cent level
C. D. at 1 per cent level = 1·01 ft.
S. E. per cent = 3·23

The effects due to years and treatments are both significant at 1 per cent level and the combined effect of the treatments and year is not significant.

The maximum plant height has been attained at 5 lb. seed rate per acre and a seed rate of 10 lb. per acre comes in the same group at 1 per cent level of significance.

Lowest plant height is recorded with the highest seed rate, *i.e.*, 40 lb. per acre. There is, however, no significant height differences between 20, 25, 30 and 35 lb. seed rates per acre at 1 per cent level.

Base diameter

Records on the average base diameter of plants for 3 years are given in Table V and the analysis of variance in Table VI.

TABLE V

Base diameter of plants

Seed Rate (per acre)	Average base diameter of plants (in cm.)			Base diameter of plants in cm. (average of 3 years)
	1952	1953	1954	
5 lb.	1·66	1·58	1·70	1·65
10 lb.	1·56	1·16	1·22	1·31
15 lb.	1·34	1·07	1·09	1·17
20 lb.	1·16	0·90	0·88	0·98
25 lb.	1·19	0·95	0·83	0·99
30 lb.	1·22	0·77	0·80	0·93
35 lb.	1·15	0·83	0·75	0·91
40 lb.	1·20	0·86	0·64	0·90
P	·01	·01	·01	·01
C. D.	0·304	0·29	0·49	0·22
S. E. per cent	5·95	7·29	12·72	5·22

TABLE VI

Analysis of variance of base diameter of plants

Source of variation	D. F.	S. S.	M. S.	F.
Year	2	2·5394	1·2697	25·394**
Block (within year)	12	0·6117	..	..
Treatment	7	7·1801	1·0257	20·514**
Treatment × year	14	0·3626	0·0259	..
Error	84	4·2012	0·0500	..
Total	119	14·8950	..	..

** Significant at 1 per cent level
C. D. at 1 per cent level = 0·22 cm.
S. E. per cent = 5·22

The effects of year and treatment are highly significant and their interaction is not significant. Table V shows that the treatment of 5 lb. seed rate per acre has given significantly higher base diameter of plants than all the other treatments at 1 per cent level.

Like plant height, lowest base diameter is recorded at 40 lb. seed rate per acre and it also falls in the same group with the seed rates from 20 to 35 lb. per acre.

Plant population and mortality study

Records on plant population at harvest for the three years and mortality percentage due to different seed rates have been represented in Table VII and the analysis of variance in Table VIII. Theoretical stand per acre has been calculated on the basis of 80 per cent germination of the seeds.

TABLE VII

Plant population and mortality percentage

Seed Rate (per acre)	Theoretical stand per acre	Actual stand per acre at harvest			Actual stand per acre at harvest (av. of 3 years)	Mortality per cent
		1952	1953	1954		
5 lb.	102150	84039	73348	90801	82729	19·01
10 lb.	204300	150229	120957	174170	148452	27·34
15 lb.	306450	192385	202924	222754	206021	32·77
20 lb.	408600	214987	246116	300823	253975	37·84
25 lb.	510750	218215	264819	389736	290923	43·04
30 lb.	612900	231161	313342	409717	318073	48·10
35 lb.	715050	206702	347518	444533	332918	53·44
40 lb.	817200	256382	359611	481238	365744	55·24
P	·01	·01	·01	·01	·01	..
C. D.	..	95418	106927	136564	68537	..
S. E. per cent	..	16·96	11·37	11·12	7·38	..

TABLE VIII

Analysis of variance of plant population

Source of variation	D. F.	S. S.	M. S.	F.
Year	2	12607031	6303515·5	28·691**
Block (within year)	12	11582335	965194·5	..
Treatment	7	43212549	6173221·3	28·098**
Treatment × year	14	7110823	507915·9	2·312**
Error	84	18455096	219703·5	..
Total	119	92967834	..	..

** Significant at 1 per cent level
C. D. at 1 per cent level = 68537
S. E. per cent = 7·38

The effects due to year, treatment and their interaction are highly significant. It is clear from Table VII that the minimum final stand (82,729) at harvest has been obtained in 5 lb. seed rate per acre and the number of stand generally increased with the increase in seed rate, the maximum being obtained at 40 lb. seed rate per acre (35,6744).

Mortality of plants, however, increased as the seed rate is increased starting from 19·01 per cent with 5 lb. per acre seed rate, it gradually increased to 55·24 per cent with 40 lb. per acre seed rate.

DISCUSSION AND CONCLUSIONS

The study of the foregoing observations indicates that, on the one hand, with higher seed rate per acre a greater population at harvest is obtained while on the other a lower seed rate in spite of low population has given higher yield of fibre. This increased yield of fibre may be attributed to the vigorous growth of almost all the potential plants produced at such low seed rates.

A comparison of 5 lb. and 10 lb. seed rate per acre shows that though maximum height and basal diameter of plants are attained in the 5 lb. treatment, maximum fibre yield is, however, obtained when 10 lb. seed rate is employed. An examination of the number of plants harvested shows that in the former seed rate the population is 82,729 whereas in the 10 lb. seed rate the number is 1,48,452. Thus the optimum stand is obtained when a seed rate of 10 lb. is used.

From the mortality study (Table VII) it may be noted that in the case of 40 lb. seed rate per acre though the seeds were sown at eight times the rate as 5 lb. seed rate per acre, in the former treatment 55·23 per cent of the theoretical population died, while only 19·01 per cent of mortality was recorded in the latter seed rate. Thus it is seen that regardless of high variation in seed rates, the variation in plant

population at harvest is not marked. Crane and Acuna [1945] recorded a similar observation in *Urena lobata*, a bast fibre crop and they stated that one of the reasons for such high rate of mortality in higher seed rates was the self thinning of plants resulting from high competition between them. The behaviour observed in *H. sabdariffa* also is similar and a high percentage of mortality is recorded in the higher seed rates due to competition between the plants for existence.

It may be stated that application of higher seed rates in *H. sabdariffa* usually results in low yield of fibre due to poor development of plants and high rate of mortality. Thus it seems that the soil under certain conditions can support an optimum number of plants beyond which it involves a huge waste in plant material and a corresponding drainage in soil nutrition.

It is concluded that use of heavier seed rates in *H. sabdariffa* is quite wasteful and a seed rate of 10 lb. per acre seems to be adequate for broadcast sowing of Roselle.

Summary

A seed rate experiment with *H. sabdariffa* L. with eight different seed rates—5, 10, 15, 20, 25, 30, 35 and 40 lb. per acre in randomised blocks with five replications was conducted at the Jute Agricultural Research Institute, Barrackpore, for three years during 1952-54.

Highest fibre yield has been obtained with 10 lb. of seed rate per acre and a further increase in the seed rate resulted in the progressive fall in fibre yield.

There is a progressive decrease in the average plant height and basal diameter of plants with the increase of seed rates.

There is a progressive increase in the mortality of plants with the increase of seed rates.

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EFFECT OF BURYING SANNHEMP AS GREEN MANURE ON THE YIELD OF WHEAT

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THE effectiveness of green manuring as a promising practice for maintaining productivity of soil is now well known. In an earlier paper while reviewing the subject of green manuring, the senior author of this article had referred to the lack of knowledge of green manuring as one of the main causes responsible for its lack of application by the farmers on large scale. In a country where two-thirds of cattle manure is converted into smoke by choice, on account of its lower cost, green manuring has drawn the attention of progressive farmers.

In order to draw maximum benefit from this practice one should have clear understanding of cultural processes involved. The sowing of green crop may be so arranged that its burial receives sufficient time for its decomposition and production of nitrates. It should, however, not be forgotten that the following crop must also be in readiness to take up nitrates without any loss due to leaching.

Detailed experiments are, therefore, necessary to develop a techinque which may both be feasible and practicable. An investigation lasting for four year was started in 1950-51 at a farm attached to Agronomy Division of the Indian Agricultural Research Institute, New Delhi. The green manure crop was every year followed by wheat.

Soil

The soil of experimental plot was sandy loam of average fertility with small saline patch observed on one side of the field. The chemical composition of top 6 inches of soil is given below :

Nitrogen	0·06 per cent
Available P_2O_5	Traces (0·01 per cent)
Available K_2O	0·0448 per cent
Total P_2O_5	9·0158 per cent
Total K_2O	0·415 per cent
Total soluble salts	0·156 per cent
*p*H	7·9

Climate

Delhi falls under a subtropical and semi-arid region with an average rainfall of 25 inches. Most of the precipitation is received from mid July to mid September. The average maximum temperatures (106°F to 116°F) are observed in May and June and the average minimum of 45°F during January.

Experimental

The experiment was laid out in a split-plot design with 4 replications and following treatments.

Main plot (time interval)

A. Sannhemp buried after 4 weeks of sowing

B. Sannhemp buried after 6 weeks of sowing

C. Sannhemp buried after 8 weeks of sowing

D. Sannhemp buried after 10 weeks of sowing.

Sub-plot (Doses per acre)

X. Superphosphate. 80 lb. P_2O_5 at the time of sowing sannhemp.

Y. Ammonium sulphate. 15 lb. N, at the time of burying sannhemp.

Z. X × Y.

T. Control (no fertilizer).

Results

The findings of the investigation have been summarised in the following Tables.

Table I

Total green matter and nitrogen added (1950-53)

Treatments	Total green matter lb. per acre	Percentage nitrogen in plants (dry basis)	Total nitrogen added per acre by plants	Total nitrogen in soil before sowing wheat	Interval between burying of green crop and sowing wheat
A	11564·25	2·58	56·29	0·066	87
B	17476·25	2·27	88·37	0·079	71
C	24306·50	2·11	124·77	0·081	58
D	32003·25	1·42	128·39	0·067	44

From Table I it would appear that the quantity of green matter increased with the age of the crop. Though the percentage of nitrogen was highest in the young stages but the total nitrogen added was more as the crop advanced in age. In case of treatment C the 'time' interval was the same both for burying green crop and sowing wheat.

TABLE II

Effect of burying interval on the yield of wheat

Treatments	1950-51	1951-52	1952-53	1953-54	Average
A	18·91	14·25	20·77	17·12	17·76
B	17·42	11·36	24·33	18·61	17·93
C	23·38	17·54	26·95	21·23	22·27
D	17·63	14·70	23·50	16·89	18·18
'F' test	Sig. 1 per cent	Sig. 1 per cent	Not Sig.	Sig. 1 per cent	Sig. 1 per cent
S. Em ±	1·03	0·60	1·43	0·68	0·38
C. D. at 1 per cent	4·71	2·78	..	3·17	1·74

The differential response shown by main-plot treatments is highly significant at 1 per cent level, and the best yield was obtained from treatment 'C', i.e. sannhemp buried after 8 weeks of sowing. This treatment irrespective of seasonal variations, has consistently given highest yield. Differences between other treatments are negligible. Treatment 'C' has over-yielded others by about $4\frac{1}{2}$ maunds grain per acre.

TABLE III

Effect of fertilising green manure crop on the yield of wheat

Treatments	1950-51	1951-52	1952-53	1953-54	Average
X	20·89	15·98	24·14	20·16	20·29
Y	18·64	12·75	24·75	17·03	18·29
Z	19·77	17·65	25·53	20·00	20·74
T	18·03	11·47	21·13	16·67	16·83
'F' test	Sig. 5 per cent	Sig. 1 per cent	Not sig.	Sig. 1 per cent	Sig. 1 per cent
S. Em ±	0·79	0·73	1·45	0·44	0·51
C. D.	1·89 (5%)	2·84 (1%)	..	1·62 (1%)	1·97 (1%)

A Significant response between sub-plot treatments was also observed. On an average an increased yield of $3\frac{1}{2}$ maunds per acre was obtained with treatment 'X' (80 lb. P_2O_5) and about 4 maunds with 'Z', though nitrogen alone at the rate of 15 lb. per acre did not produce appreciable difference.

TABLE IV

"Interaction" between treatments (yield of grain in maunds per acre)

Treatments		A	B	C	D	
1950-51						
	X	20·67	17·39	25·42	20·07	
	Y	19·58	17·51	21·16	16·30	Not Sig.
	Z	18·49	18·24	23·84	18·49	S. Em. ± 1·49
	T	16·91	16·54	23·11	15·57	
1951-52						
	X	15·81	12·03	20·05	16·04	Not Sig.
	Y	12·92	10·02	14·26	13·81	S. Em. ± 1·47
	Z	16·26	13·81	22·94	17·60	
	T	12·03	9·58	12·92	11·36	
1952-53						
	X	18·15	24·06	29·40	24·95	
	Y	23·17	24·50	26·51	24·83	Not Sig.
	Z	21·27	28·74	29·18	22·94	S. Em. ± 2·90
	T	20·49	20·04	22·72	21·27	
1953-54						
	X	18·74	20·75	23·07	18·09	
	Y	15·62	18·10	19·33	15·05	Not Sig.
	Z	19·04	20·22	22·61	18·12	S. Em ± 2·92
	T	15·07	15·39	19·89	16·32	
Average of 4 years						
	X	18·34	18·56	24·48	19·79	
	Y	17·82	17·53	20·31	17·50	Not Sig.
	Z	18·76	20·25	24·64	19·29	S. Em ±1·03
	T	16·12	15·39	19·66	16·13	

Though ' interaction ' has not been found significant in any year, the differences are conspicuous. Like individual treatments the yield reflected by a combination of C with X was best of all treatment combinations. A difference of 4·82 maunds per acre was noted over C thereby indicating the importance of phosphate application to green manure. From practical point of view, it is obvious, the best use of mineral phosphatic fertiliser is made when sufficient organic matter is present in the soil. The chances of reversion are considerably minimised as organo-phosphates are mobile in the soil.

The effect of treatments on the grain quality is presented in Table V and VI.

TABLE V

Protein content of wheat grain (percentage)

Treatments	A	B	C	D
	12·15	12·34	13·56	12·08

It is apparent from the Table V that not only the quantity but also quality was improved by treatment ' C '.

Table VI indicates, the state of decomposition of organic matter in soil.

TABLE VI

(C/N ratio)

Treatments	A	B	C	D	X	Y	Z	T
	6·32	6·25	6·28	7·50	5·96	6·73	6·66	6·60

A wider ratio, as expected, was observed in treatment D where the period was short and a heavy crop buried at a relatively advanced age. A casual observation on a small patch with slight salinity revealed at the close of the investigation a decline in *p*H from 8·1 to 7·3.

DISCUSSION

On further examination of data it would be seen in Table I that the total green matter and nitrogen were increased with the age of crop. That the state of decomposition was better as reflected on wheat yield might be seen in treatment ' C ' where the percentage of nitrogen was also highest in soil.

The effect of ' timings ' on the yield of wheat appears to be dominent (Table II). Time taken in turning under sannhemp, and sowing of wheat since almost coincided in treatment ' C ', which has given the highest return. In the case of other

treatments, however, the interval between burial and sowing of subsequent crop was either too short or too long, resulting in the waste of plant food. The correct ' timings ' appear to be 8 weeks either way. Sethi [1928] also found sannhemp adding maximum amount of nitrogen at 60 days. Coleman *et al.* [1912] and Rege [1941] suggest flowering stage as best time for burying green crop. Hutchinson and Milligan [1914] showed decrease in nitrate contents of soil after 8 weeks of burial of sannhemp.

Table III indicates a remarkable effect of phosphate application on the yield, of wheat. Addition of nitrogen to phosphate did not make much difference except perhaps, giving a little kick off. A perusal of Table IV would show that interaction between treatments is not significant. This does not, however, minimise the effect of phosphate which was doubled in the case of ' C '—the best ' time ' for ploughing in of green crop. The beneficial effect of phosphate manuring of legumes has been noted besides others by Bailey [1930], Reynolds and Smith [1946], Parr and Bose [1947] and Raychaudhri and Subbiah [1954].

Summary

Summing up, it may be safe to conclude that green manuring is a practice of ' timings '. In case of failures correct timings should be looked into. The whole technique is based on this simple factor, viz., correct intervals between sowing of green manure. its burying under and sowing of wheat crop succeeding it (8 weeks in both cases). If properly done this would furnish an additional return of about 5 maunds grain and 15 maunds straw which might offset the so called loss of one crop season. Application of phosphate in conjunction with green manure is profitable.

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STUDIES ON THE TRANSPLANTATION OF SEEDLINGS OF CASHEW (*ANACARDIUM OCCIDENTALE* LINN)

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(With 1 Text Fig.)

THE transplantation of cashew seedlings is not generally very successful as many of them die in the process. Sowing of seeds at stake is, therefore, preferred. Even this practice, however, has its own drawbacks because the germinating seeds with their sweet fleshy cotyledons often fall a prey to rodents, jackals, monkeys, crows and other pests. Management of the young seedlings in the hilly terrain over wide areas also offers exceptional difficulties. Moreover, the method restricts the scope for a rigorous selection of the planting material. For all these reasons, it was felt that it would be worthwhile if a successful method of transplanting seedlings raised at first in a nursery could be evolved. Such a method would further facilitate, incidentally, the shifting of budded and grafted plants produced in nursery beds. Trials towards this end were conducted at the Cashew Research Station, Mangalore for nearly 18 months in 1953-55.

Review of Literature

Tai and Topper [1947] appear to be the only workers who have reported on trials on cashew transplantation. Their treatments included the severing of tap root a few weeks before transplantation and heading back the shoots at the time of potting. No advantage was seen in severing the tap root alone ; the highest proportion of survival was gained when plants with undisturbed tap roots were severely headed back to reduce the aerial portions to one-third of the normal when potting the lifted seedlings. Morada [1941] and Paul [1936] also mention difficulties experienced in transplanting cashew seedlings but there is no record of any work towards overcoming this drawback. Dealing with transplantation of teak seedlings, Troup [1921] described a successful experiment carried out several years ago in Tharrawaddy forests. A small patch was cleared and burned and in it planted thickened root stocks of young natural teak plants which had been killed back repeatedly by fire or suppression. The stems ware pruned down, the roots were trimmed and thickened root stocks planted with success.

Material and Methods

The trials at the Cashew Research Station, Mangalore were in the first instance directed towards determining the optimum age of the seedlings for transplantation and the months when they could be successfully transplanted. Cashew seeds of uniform size and weight obtained from the Agricultural Research Station, Taliparamba, were sown in monthly intervals from November, 1953 to December, 1954. The first batch of five seedlings from November 1953 sowings were transplanted in December, 1953, when they were one month old and lots of five seedlings from this batch were transplanted in each month thereafter so as to provide for all age groups ranging from one month to 12 months. Similarly, the seeds sown in December, 1953 provided one month old seedlings in January, 1954 and one year old seedlings in December, 1954. The sowings thus made till December, 1954, provided for transplantation of seedlings ranging in age from one month to 12 months in each of the 12 months of the year.

The later trial was aimed at determining the influence of the following treatments on the success obtained in transplantation of the seedlings.

(i) Severing the tap root of the seedlings six weeks prior to transplantation,

(ii) severing the tap root four weeks prior to transplantation,

(iii) heading back the shoot to one-third of its height, clipping the leaves to half their size and potting the seedlings immediately and

(iv) potting the seedlings without any prior treatment (control).

Ten six-month old seedlings were employed for each of the above treatments and the trial was commenced in December, 1954. In the first two treatments, the tap root of the seedling was cut at a depth of nine inches with a sharp knife. To ensure uniformity, the lifting and potting operations with all the seedlings were done by the same operators. The plants were removed carefully from the beds and placed in hill grass containers, nine inches long and four inches in diameter and made to fit by packing loose earth all round at the sides. The pot with the plant was then placed under shade and watered once daily. In the treatments, where the shoots were headed back, the cut ends were coated with paraffin wax, the subsequent nursing being the same as for the other batches.

Results

An assessment of the results of the preliminary trial, to determine the optimum age of the seedlings and the month when they could be successfully lifted from the beds, was made at the end of November, 1954. The results are summarised in Table I.

TABLE I

Mean percentage of survival two months after transplantation

Age of seedling (months)	No. of batches transplanted	Percentage of survival	
		Range	Mean
One	12	60—100	95
Two	11	20—100	66
Three	10	0— 60	34
Four	9	0—100	33
Five	8	0— 80	28
Six	7	0— 20	10
Seven	6	0— 40	14
Eight	5	20— 80	60
Nine	4	60—100	84
Ten	3	80—100	94
Eleven	2	100—100	100
Twelve	1	80	80

It may be seen from the data in Table I that

(i) One month old seedlings could be transplanted with success ranging from 60 to 100 per cent at any time provided the transplanted seedlings were given shade and adequate hand watering during dry spells.

(ii) Older seedlings between two and seven months, which are particularly suitable as rootstocks in budding and grafting operations were however, found to succumb in the process.

(iii) Seedlings eight months old and above could be transplanted more successfully than those belonging to the younger age groups between two and seven months old.

A study of the data with reference to the success obtained in each month of the year failed to reveal any correlation between the percentage of survival and the weather conditions prevailing during each of the months. The percentge of success even during the rainy months of June, July and August which are normally considered suitable for transplantation worked out only to 26, 38 and 52 respectively as against 40, 44 and 60 per cent recorded in March, April and May respectively which represent the summer. The success in the other months was varying and

inconsistent and bore no relation to the weather conditions. It was thus apparent that the age of the seedlings was more likely to be the factor determining the ultimate success in transplantation than the season of operation.

The first batch of seedlings in the modified trial with six month old seedlings under four treatments was transplanted on the 7th December, 1954. A week after potting, many of the leaves of the seedlings whose tap roots had been cut and the ' controls ' which had been allowed to remain intact dried up and were shed, leaving the stem bare. By the third week, 50 per cent of the seedlings whose tap root had been cut had dried completely while the remaining seedlings of this batch as also of the 'controls ' had dried to within nine inches of ground level. At the end of the fourth week, new buds commenced breaking in on 80 per cent of the seedlings headed back to one-third height, 10 per cent of the seedlings whose tap root had been cut four weeks earlier and 20 per cent of ' controls ' and these continued to grow till the end of the period of the experiment, whereas all the seedlings with tap root cut six weeks earlier had succumbed.

Encouraged by the high percentage of survival obtained when the seedlings were headed back to one-third height, a new treatment, viz. heading back the shoots to half the height and clipping the leaves to half their size and potting immediately was included during the January, 1955 operations, when seven month old seedlings were transplanted. This treatment was included with the special object of transplanting seedlings with longer stems for use in budding and grafting operations. The trial with the five treatments was continued during February, March, April, May and June, 1955 when 8, 9, 10, 11 and 12 month old seedlings respectively, were transplanted. The success obtained by the various treatments is summarised in Table II.

TABLE II

Cashew-transplantation trial-data on survival number alive out of ten

Treatment	6 months old* Dec. '55	7 months old* Jan. '55	8 months old* Feb. '55	9 months old* Mar. '55	10 months old* April '55	11 months old* May '55	12 month old* June '55	Mean
1. Tap root cut six weeks earlier	0	1	2	6	8	6	7	4·3
2. Tap root cut four weeks earlier	1	3	3	6	5	6	6	4·3
3. Shoots cut to $\frac{1}{3}$ height	8	9	10	9	10	10	10	9·4
4. Shoots cut to $\frac{1}{2}$ height	1	9	10	7	10	10	10	9·3
5. Control	2	1	10	7	10	8	9	6·7

* Transplanted in

It would be seen from Table II that heading back plants to one-third of half their original height is a promising method of transplanting cashew seedlings. It is interesting to observe that even the untreated eight-month and older seedlings have recorded a higher percentage of success ranging from 70-100 in transplanting. This result is in conformity with those of the preliminary trial in which seedlings eight month old and above recorded higher success than those of the younger age groups.

With a view to determine the causes for this behaviour and in particular to study whether the nature of root growth has any influence on the ultimate survival, 10 seedlings in each of the age groups from one to 12 months were lifted from the beds and observations on the nature of tap root growth and the number of lateral and fibrous roots produced were recorded. Table III summarises the data.

TABLE III

Root characters of cashew seedlings of various age groups. Ten seedlings examined in each age group

Serial No.	Age of seedling (months)	No. of lateral roots	No. of fibrous roots on the tap root	Remarks
1	One	0	63	No lateral roots could be seen. Only fibrous roots were present.
2	Two	0	67	
3	Three	1	67	
4	Four	1	68	
5	Five	2	64	Only one or two lateral roots could be distinguished. The rest were all fibrous roots.
6	Six	1	68	
7	Seven	2	65	
8	Eight	4	53	
9	Nine	4	53	The lateral roots were well defined but slightly thinner than the tap roots. Fibrous roots were also presents in abundance.
10	Ten	6	69	
11	Eleven	6	69	
12	Twelve	6	54	

Note : Each lateral root had between 30 and 60 fibrous roots.

It is seen from the above data that the higher percentage of survival noticed in the eight-month and older seedlings may be due to the production of lateral roots which together with the tap root and the numerous fibrous roots have presumably helped the establishment of the plant, at the same time, replenishing the loss by transpiration through greater absorption of moisture. The younger batches, on their other hand, have had to depend solely on the tap root which in the process of lifting was invariably damaged. In the absence of sufficient root regeneration through lateral roots, coupled with the loss of moisture by transpiration, the seedlings had failed to recover after transplantation. These seedlings had, however, exhibited a remarkable rate of recovery when the top growth was reduced to a third or half.

Fig 1.
Cashew transplantation—the first plant shows a seedling cut back, the second and third the sprouting of the seedling. The fourth is an untreated seedling showing withering.

Transplantation in summer

In order to test the efficacy of these treatments with one year old seedlings in the summer months, 40 seedlings were transplanted to grass containers every month from February to May 1955. The success obtained is summarised in the Table IV.

TABLE IV

Cashew transplanting trial—success during summer months

Serial No.	Treatment	No. alive out of ten				Mean
		February	March	April	May	
1	Heading back to $\frac{1}{3}$ height	5	8	10	10	8·3
2	Heading back to $\frac{1}{2}$ height	9	10	7	10	9·3
3	Control (untreated)	6	5	7	6	6·0

It is evident from the data in Table IV that even one year old seedlings can be transplanted successfully during the summer months by heading back the shoots to one third or half of their height at the time of transplantation.

Discussions

The results of the investigation show that transplantation of cashew seedlings is not only feasible but can be successfully attempted in the summer season even with one year old seedlings by adopting such treatments as heading back shoots at the time of transplantation. It is interesting to note that while the older seedlings could be lifted with greater degree of success even without any pre-treatment, it was only the younger age groups between three to seven months which presented some difficulty, resulting in casualties after transplantation. This peculiar feature led to the study of the role played by the root system of the seedlings. The important function of the lateral and fibrous roots is amply demonstrated by the failure of the younger batches in which the lateral roots were practically absent. In the younger batches of seedlings (between three and seven months), the absorptive capacity at the time of transplantation remains at the level to which it is reduced during the operation for a considerable time, while the transplantation from the vigorous aerial portions continues resulting in the drying up of the tissues beyond recovery. Seedlings below two months by virtue of their limited top growth and tap root penetration seem to fare better.

The success in transplantation when the shoots are headed back, irrespective of the age of the seedlings for season of operation is a significant result especially when viewed against the background of the preliminary indications of failure with the younger batches of untreated seedlings and leads one to the conclusion that the absence of lateral roots need not be a limiting factor to success, so long as the transplanted seedling receives a treatment which tends to maintain an even balance between water absorption and transpiration at the time of transplantation. The reduction of the top growth is a treatment by which the degree of success could be improved. These observations are in conformity with those of Tai and Topper [1947] and Troup [1921].

The inconsistent results obtained in the different months of the year with the untreated seedlings and the high percentage of success achieved in all seasons including the summer when the seedlings were headed back indicate that the success in transplantation need not necessarily be associated with the weather conditions prevailing at the time of operation provided the transplanted plants receive adequate shade and watering.

The ease with which the plants withstand the shock of heading back and transplantation is also noteworthy in view of the possibilities of raising seedlings in nursery beds which could be lifted at will either for planting out in the field or for use as rootstocks in grafting operations. The result is of particular significance because seedlings raised in pots and other containers do not grow as quickly or vigorously as those raised in beds.

While it may not be normally necessary to resort to transplanting for raising plantations in localities free from fear of depredations from animals and rodents, it is an inevitable procedure in forest and other areas in the remote hilly tracts

where cashew is abundantly grown and where any amount of care and expenditure in raising nurseries and transplanting cannot be considered a waste. In some forest areas in the Western ghats and in parts of Ceylon and Burma, the practice of raising seedlings in coffee baskets which are set out as such is already in vogue and the results reported in this note indicate the possibility of proceeding one step further, viz. of raising seedlings on a large scale in sheltered areas in the nursery in advance of the sowing season, say March or April. The seedlings so raised could be set up in the field in the following June with the break of the monsoon. No large scale work on budding and grafting is yet in evidence in private cashew plantations. With the progress of research work on the crop, particularly in the vegetative propagation methods among which budding and grafting are bound to play an important role, the need for production of workable rootstocks on a large scale will undoubtedly by a great problem, especially in view of the difficulty experienced with seedlings raised in pots and other containers. In the above context the results of the present investigation are of significance.

Summary

1. One month old cashew seedlings could be transplanted successfully during any month of the year without any pretreatment provided the seedlings were given adequate shade and water.

2. Heading back the shoots to one-third or half their height at the time of transplantation was found to be successful. Even one year old seedlings responded to the treatment with success ranging between 80 and 90 per cent during the summer months.

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FACTORS AFFECTING THE INCIDENCE OF SMUTS IN OATS*

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(with 5 Text Figs.)

THE study of the role of environmental factors in the development of plant diseases is not only important to plant pathologists, but also to those interested in the development of disease resistant varieties. The work of the latter nature would be seriously handicapped in case the investigator can not produce at will the disease in an epidemic form.

Smith [1911] was one of the firsts to emphasize the importance and also the complexity of the relation of environment to parasitism. Since then several workers have been engaged in a more thorough and comprehensive study of this subject.

The present investigations were undertaken to study the reaction of oat smuts under different conditions of temperature and light. Some experiments were conducted in the Green-house attached to the New York State College of Agriculture at Cornell University (U.S.A.).

Host and the pathogen

1. *Host.* The oat plant belongs to the family Graminae and genus Avena Its inflorescence is a panicle, which may be spreading (equilateral or tree-like) or one-sided (Unilateral or banner-like). By far, the greater number of cultivated varieties are of the " Spreading panicle " type. The grain is produced on small branches in spikelets, varying in number from 20 to 150 per panicle. The number of florets or grains in each spikelet, except in the hull-less or naked oats, is usually two. The kernel is tightly enclosed within the lemmas or inner glumes and palea. The kernel, or more properly the caryopsis, constitutes about 65 to 75 per cent of the total weight of the grain.

2. *Pathogen.* The oat smuts are caused by two distinct but closely related pathogens the loose and covered smut fungi :

The loose smut fungus—*Ustilago avenae* (Pers.) Rostr.

Syn.—(Uredo segetum subsp. avenae Pers.)
(*Uredo carbo* var. *avenae* DC.)

* A portion of the thesis submitted to the Cornell University (U.S.A.) for the degree of Doctor of Philosophy.

(*Ustilago segetun* var. *avenae* Jens.)
(*Ustilago avenae* Jens.)
(*Ustilago avenae* (Pers.) Jens.)

The covered smut fungus—*Ustilago kolleri* Wille
Syn.—(*Ustilago avenae* var. levis Kell. and Swing.)
(*Ustilago levis* (Kell. and Swing.)
Magn.)

In the field, it is difficult to distinguish one from the other. The economic loss is similar in both the cases. The glume instead of having a well developed grain is filled with a dark or brown to black sooty mass of chlamydospores (in loose smut even the glume is replaced by spores).

As the name indicates, the chlamydospores of loose smut are seen in the air, a shortwhile after the head emerges out of the leaf, while those of covered smut are not detachable with the same ease, and, therefore, begin to scatter sometime later. In an epidemic form, particularly when the infection has taken place under the most favourable environmental conditions, elongated lesions develop on the blade of the flag leaf and sometimes on the leaf next to it Fig. 1.

Two types of infection are recognized at present ; i.e. infection of the flower and the seedling. In the first case, the spores in the air (of which there are plenty at the blooming time) land on the stigma Fig. 2. These germinate and the mycelium travels downward, invading the pericarp and remaining there in or on it as resting mycelium.

Some spores may fall later on the embryo and germinate there. The spore contamination may also take place at the time of threshing. This may be the cause of the second kind of infection.

In the seedling infection, the mycelium enters the young seedling, keeps pace with the growing point, and repeats the circle at heading time.

Review of Literature

The investigations on the influence of environmental conditions upon the development of the diseases of field crops have expanded a great deal since Soraner's early work. Wilson [1932] has prepared a bibliography, which contains about 4,000 references on this subject. Kellerman *et al.* [1890], Clinton [1900], Ravn [1901], Hiltner [1907], Heald [1919], Reed and Faris [1924], Johnston [1927] are some of the other workers, who studied the influence of environmental factors on the development of smut in Oats. Hansing [1945] has reported, that in 1944, soil was very cold and wet between planting and very low emergence of the inoculated seed and infection was obtained, especially in the oats, which had previously shown an intermediate susceptibility. Sampson [1929], on the other hand, reported, that different sowing dates had no effect on infection under the conditions of her experiment.

To get a better understanding of the different factors (both of soil and atmosphere) affecting the infection by smuts in oats, it was realized, that each one had to be fully analysed and its influence studied separately.

Fig. 1. Leaf infection: (a) Leaves free of smut, (b) Leaves infected with smut.

Fig. 2. Part of panicle showing the opening glumes after self-fertilization.

The two most important factors, that greatly influence the infection of oats by the smut pathogen, are soil temperature and moisture. Brefeld, Reed and Faris [1924] germinated inculated oats at 7°C. and at 15°C. and got 40 to 46 per cent infection in the former and 27 to 30 per cent in the latter, showing a decidedly higher infection at the lower temperatures. According to him, oats germinate very slowly at low temperature and the pathogen is able to penetrate and reach the growing point of the suscept, before it emerges from the soil, while at higher temperature, it grows rapidly and thus the pathogen has little chance to get established in the tissue of the growing point. Hecke [1909] emphasized the three-fold influence of temperature, i.e (i) the direct effect of temperature upon the germination of smut spores and of the seed, (ii) the influence on the duration of the susceptible stage of the host plant and (iii) its influence upon the possibility of the fungus reaching the growing point of the host.

Similar results have been reported by Bartholomew *et al.* [1932] showing, that low soil moisture within a certain temperature range were accompanied by relatively high percentages of smut infection, while high soil moistures, combined with high soil temperatures, resulted in complete elimination of the fungus. Reed and Faris [1924] also found a definite relationship between soil moisture and temperature with the percentage of infection in oats.

Reed [1938] emphasized the importance of environmental factors like temperature and water content of the substrata, especially during the period of germination of inoculated seeds, since according to him the subsequent development of the oat plant did not seem to influence the fundamental resistance or susceptibility to the smuts.

Evidence is also available showing that air temperature and humidity assume the same importance as that of soil at the time of spore dissemination [reviewed by Wilson, 1932, Foister, 1935 and 1946].

Material and Methods

1. *Variety used and its natural susceptibility*

Variety *Mabel* was used for these studies. It is an early maturing and high yielding variety. Its infection under natural conditions during the period of 1944-46 varied from as high as 50 per cent to as low as 17 per cent.

2. *Inoculum*

The inoculum used in this study was collected from the diseased panicles of the oat plants grown in the Plant Breeding Test Garden, and consisted of the black sooty chlamydospores of the loose and covered smut pathogens. Infected panicles were placed, after collection, in paper bags, which were spread out to dry, before being stored away for winter in cold storage rooms at 35°F. In this way, the spores remained viable till they were taken out for use at sowing time.

The chlamydospores were finally obtained, relatively free from the fragments of the host plant, by rubbing the dry infected panicles against cheese cloth held tightly over a petri dish. The spores were stored in jars.

3. *Smut spore germination test*

The spores were first tested for viability in 5 per cent sucrose solution. Only that lot of spores, which gave more than 60 per cent germination was used for inoculation.

4. *Dehulling and inoculation*

Heavy infection of seedlings, infected by smut, is obtainable by inoculation of seeds with viable spores of the pathogen. The spores must come in contact with the caryopsis. For oats, there are two methods : (i) hull removal and dusting of caryopsis with dry chlamydospores, and (ii) replacing by vacuum pump the air beneath hull with a water suspension of chlamydospores. Both methods place the inoculum successfully upon the caryopsis. Different investigators [Rosentiel, 1929 ; Bayles, 1929, Kolk, 1930 ; Zade, 1933; Tapke, 1936 ; Leukel, 1937, 1938 ; and Tarvet, 1944] have reported upon the superiority of one method over the other. It appears, however, that infection can be readily obtained by either method, provided initial favourable environmental conditions exist during the first week or so after sowing.

The first method was adopted in these studies. The hull of the seed was removed with the help of a dehulling machine [Love, 1944], which proved very handy. Dehulled seeds were taken in small lots at a time, and enough spores were dusted over them. The excess spores were later sieved off. Plenty of spores were retained in the fine hair, which covered the seed all over. Some spores were also retained in the longitudinal groove. The eccentric embryo, which is externally and superficially placed on one side at the lower part of the grain is not smooth. There are fine ridges and furrows. Some spores get into these depressions also. Thus, dehulling facilitated the retention of many spores on different parts of the grain kernel. The smutted seeds were put in small envelopes and placed in the cold storage room. These were taken out at the time of sowing.

Procedure

The procedure adopted to carry out the various treatments is described below :

1. *Temperature*

To keep the soils at a constant temperature, water tanks were used (5 ft. × 6 ft. × 8 ft.). The higher temperatures were maintained by heating the water electrically and controlling the temperatures within one degree by thermostats. The lower

temperature was maintained by running tap water. In latter case, the temperature of the soil ranged from 55° to 53°. To keep the temperature of the water at the same degree throughout the tank, a small electric stirrer attached to the inside wall of the tank was used. This kept the water in circulation throughout the tank.

The moisture in all the pots was kept as near to the moisture equivalent as possible. The pots in the hot water tanks were watered sparingly but frequently especially during the first ten days, as it is during this period, that moisture percentage is most important.

Ten seeds were sown in each galvanized pot. The pots were thoroughly tested for any leakage before use. There were three tanks, which maintained the soil in the pots at 55°F, 75°F and 85°F, temperature. Fifteen pots were placed in each. Seeds were evenly distributed all over the surface in the pot and covered with a thin layer of soil. The control was run in ordinary earthenware pots. Due to limited space in the green-house, only five pots were used and ten seeds were sown in each for control. The temperature of the soil was recorded daily. The temperature of the control soil varied from 66° to 70°F. The pots in the tanks were filled with soil within the top two inches. The water in the tanks was kept at such a level, that the soil surface was at least half an inch below the surface of the water. Any loss in water in the tanks was made up to the original level by adding water of the same temperature as that of the tank.

The treatment was carried out for one and a half month, after which the pots were put on the benches in the green-house. Photos of the plants were taken at different intervals to show the rates of growth. Germination counts, number of plants reaching maturity, and number infected were recorded.

Light

In each flat, 40 seeds were sown, and four flats were used for 16 hours "light duration" and the same number for eight hours. For long days, the ordinary day light was supplemented by artificial light of a 500 C.P. bulb kept at a distance of three feet over the flats. Those receiving "short light duration" were kept in a frame lying next to those getting "long light durations". A thick black curtain was used to darken the chamber. The treatment was discontinued after one and a half month, when all the flats were subjected to ordinary day light. The data were recorded in terms of total number of plants heading and the number infected.

Experiments

Effect of temperature

The data are presented in Tables I, II, III and IV. A general survey of these Tables shows, that in soil temperature of 55°F, the germination started on the fifth day. In control (soil temperature 66 ° to 70°F), the germination started on the third day. In case of 75°F, the germination started on the second day ;

TABLE 1

Effect of soil temperature on smut infection of oats

Soil temperature . . . 55°F
Moisture percentage :—Highest . . . 21 per cent
—Lowest . . . 19 per cent

Pot No.	No. of seeds	Germination after number of days								Total germination	Plants reaching maturity	Plants infected
		5	6	7	8	9	10	12	15			
1	10	0	1	2	3	1	2	0	1	10	8	2
2	10	1	2	1	2	1	1	0	0	8	7	1
3	10	0	2	2	1	1	0	1	0	7	4	0
4	10	0	2	3	2	1	0	1	0	9	7	3
5	10	1	2	1	2	1	1	0	0	8	7	1
6	10	2	2	2	1	1	0	1	0	9	9	2
7	10	0	1	2	2	1	1	0	0	7	5	0
8	10	2	3	2	1	0	0	1	0	9	7	0
9	10	0	0	2	3	2	1	0	0	8	6	2
10	10	2	2	1	1	0	1	1	0	8	7	0
11	10	0	2	1	3	2	1	0	0	9	8	2
12	10	1	2	1	1	1	1	1	0	8	6	3
13	10	2	2	2	1	1	1	1	0	10	7	0
14	10	0	3	2	1	2	0	1	0	9	6	0
15	10	0	3	0	2	1	1	1	0	8	5	1

Total germination . . . 127
Per cent germination . . . 84
Total plants reaching maturity . . . 99
Per cent plant reaching maturity . . . 66
Total plants infected . . . 17
Per cent plants infected . . . 18

TABLE II

Effect of soil temperature on smut infection of oats

Soil temperature . . . 66° to 68°F (Control)
Moisture percentage :—Highest . . . 21 per cent
Lowest . . . 17 per cent

Pot No.	No. of seeds	Germination after number of days						Total germination	Plants reaching maturity	Plants infected
		2	3	4	5	6	7			
1	10	1	2	2	1	1	0	7	5	4
2	10	0	2	2	2	1	1	8	8	6
3	10	0	2	3	2	2	1	10	7	3
4	10	0	3	2	1	1	1	8	7	4
5	10	0	2	3	1	1	0	7	6	3

Total germination 39
Per cent germination 80

Total plants reaching maturity . . . .—33
Per cent plants reaching maturity 66

Total plants infected 20
Per cent plants infected 61

TABLE III

Effect of soil temperature on smut infection of oats

Soil temperature . . 75°F
Moisture percentage :—Highest . . 21 per cent
Lowest . . 18 per cent (first week)
16 per cent (second week).

Pot No.	No. of seeds	Germination after number of days						Total germination	Plants reaching maturity	Plants infected
		2	3	4	5	6	6			
1	10	2	5	0	1	0		8	6	6
2	10	0	4	4	1	0		9	7	7
3	10	3	2	2	1	2		10	7	7
4	10	0	4	4	1	0		9	6	6
5	10	2	3	1	1	0		7	3	3
6	10	0	4	4	0	0		8	4	4
7	10	2	4	1	2	1		10	8	8
8	10	0	4	2	2	0		8	6	6
9	10	0	2	4	1	0		7	5	5
10	10	0	5	2	2	0		9	4	4
11	10	0	3	4	0	1		8	4	4
12	10	0	3	5	1	0		9	7	7
13	20	1	3	3	2	0		9	6	6
14	10	0	4	2	0	0		6	2	2
15	10	0	2	4	1	1		8	4	4

Total germination 125
Per cent germination 83

Total plants reaching maturity . . . 79
Per cent plants reaching maturity . . . 52

Total plants infected 79
Per cent plants infected 100

TABLE IV

Effect of soil temperature on smut infection of oats

Soil temperature . . . . . 85°F
Moisuture percentage :—Highest . . . . . 21 per cent
Lowest . . . . . 18 per cent (first week)
15 per cent (rest of week)

Pot No.	No. of seeds	Germination after number of days					Total germination	Plants reaching maturity	Plants infected
		1	2	3	4	5			
1	10	0	4	3	1	0	8	3	3
2	10	0	5	4	1	0	10	9	8
3	10	0	6	3	0	0	9	6	4
4	10	1	5	0	1	0	7	3	2
5	10	1	5	3	1	0	10	8	8
6	10	0	4	4	0	0	8	6	5
7	10	0	7	0	1	1	9	7	6
8	10	0	4	4	1	0	9	6	4
9	10	0	6	1	0	1	8	4	4
10	10	0	2	4	2	1	9	7	6
11	10	0	3	0	0	1	4	2	2
12	10	0	4	2	0	1	7	4	2
13	10	0	7	1	0	0	8	5	3
14	10	0	5	0	1	0	6	3	2
15	10	0	6	1	1	1	9	7	7

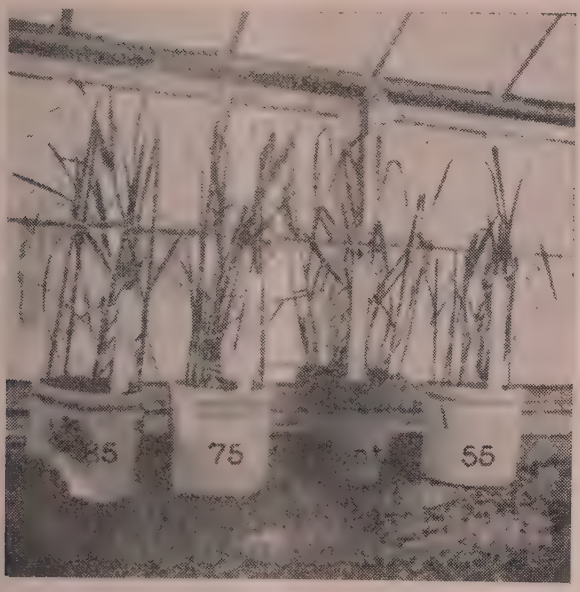
Total germination 121
Per cent germination 80

Total plants reaching maturity . . . 80
Per cent plants reaching maturity . . . 53

Total plants infected 66
Per cent plants infected 82

whereas in the soil temperature of 85°F, the germination started 24 hours after sowing. This effect may be attributed to differences in temperature rather than smutting, as it has been found, that temperature plays an important part in the germination.

While the percentage of germination was about the same in all the treatments (varying from 80-84), there were striking differences in the number of plants reaching maturity. It was 66 per cent in both the 55°F soil temperature and the control, but fell to only 52 and 53 per cent at soil temperature of 75° and 85°F respectively. This is interesting, since it is not only the amount of visible infection, which is increased as favourable soil temperatures, but also the so-called latent or hidden infection, which brings higher mortality. That such kind of latent or hidden infection does take place, has also been shown by various other investigators.



(a)

(b)

Fig. 3. The comparative growth of oat plants at different soil temperatures. (a) The day they were taken out of the temperature tanks. (b) Ten days later.

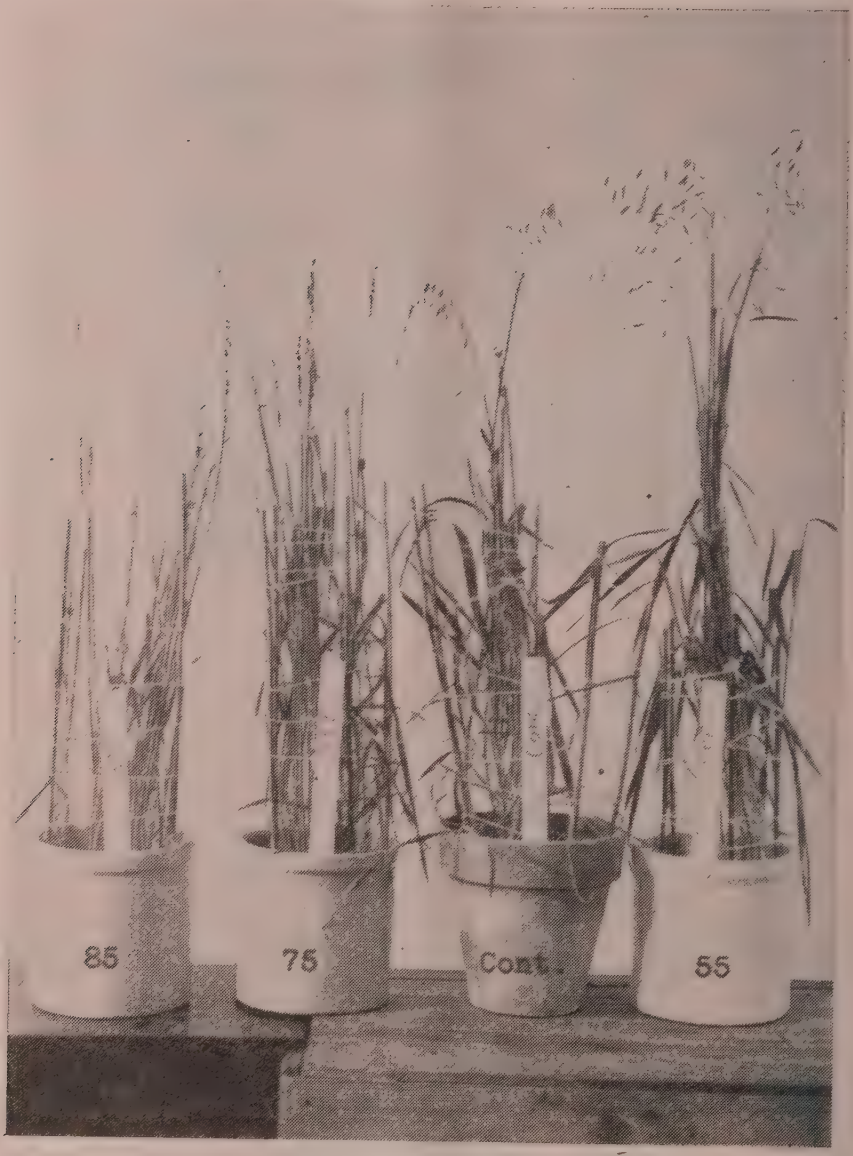


Fig. 4. The comparative growth of oat plants at different soil temperatures after heating.

Striking differences were also observed in the percentage of infection in different soil temperatures, being highest at 75°F (100 per cent), decreasing both ways. This decrease was more pronounced with the decrease of temperature than otherwise. The "t" test showed a significant difference between the soil temperature of 55°F and control, at odds higher than 99 : 1, but there was no significant difference between soil temperature of 75°F and 85°F.

General observations regarding growth of plants in different soil temperature showed that the growth at lower temperatures was slower as compared to others during the period, that the pots were lying in the constant temperature tanks. The plants in soil temperatures of 75°F and 85°F kept up a steady growth, both during and after the treatment, whereas those from soil temperature of 55°F showed a rapid growth after being taken out of the tank (Figs. 3 and 4).

Effect of light

Only the number of plants reaching maturity, and those infected, were recorded (Table V).

For each treatment, 160 seeds were sown. The number of plants reaching maturity in 16 hours "light duration" and 8 hours "light duration" were 68 and 54 respectively. Although a greater number of plants reached maturity in the former than in the latter, the difference was not statistically significant. Nevertheless, the higher mortality in case of the set, which later also gave higher infection, gives added support to similar conclusions reached in the temperature experiments. The results are interesting from the fact, that growing the plants under environmental conditions favourable for smut infection, increases not only the percentage of infection, but also the seedling mortality. This is important, both from host-parasite relationship, and also interpreting some of the inheritance results on a genetic basis, where the ratio is likely to be altered by such factors as seedling mortality.

TABLE V

Effect of different light durations on smut infection of oats

Treatment	Flat No.	No. of seeds sown	No. of plants reaching maturity	No. of plants infected	Per cent No. of plants infected
16-hour light duration	1	40	21	12	57
	2	40	13	8	61
	3	40	17	10	59
	4	40	17	9	53
8-hour light duration	1	40	14	12	85
	2	40	15	13	87
	3	40	11	11	100
	4	40	14	14	100

Total plants reaching maturity, 16 hours	68
Total plants reaching maturity, 8 hours	54
Total plants infected, 16 hours	39
Total plants infected, 8 hours	50
Per cent infection, 16 hours	57
Per cent infection, 8 hours	92
Per cent infection, control (from temperature experiment)	61

The plants reaching maturity showed a marked difference in the percentage of smut between 16-hour "light duration" and 8-hour "light duration". It was 57 per cent for 16 hours and 92 per cent for 8 hours ; the "t" value is 7·0, which is significant at odds higher than 1 per cent. The control (from temperature experiments) gave 61 per cent infection. This shows that increasing the light did not have any appreciable effect on smut infection, while a decrease in light brought an increase in smut infection. There were marked differences in the growth of the plants in the different treatments. The plants getting 16 hours light reached maturity after about one and one-fourth months and some tillers kept on coming up even afterwards, while those receiving only 8-hour light took four and one-half months to reach maturity (Figs. 5 and 6).

Discussion

It is evident from the experiments described above, that certain environmental factors influence the incidence of infection of the host by the smuts. Other investigations have contributed evidence of similar nature between the cereal smuts and their hosts.

Temperature

The results obtained in the above experiments at the soil temperature of 75°F (about 24°C) are in agreement with those obtained by Bartholomew *et al.* [1923] and Reed *et al.* [1924], but in the case of the lower temperature at 55°F, they are different.

For example, Bartholomew *et al.* [1923] found, that the reduction in percentage of infection with increase or decrease of temperature, away from the optimum, was almost the same. Reed *et al.* [1924], on the other hand, got more infection at lower temperatures than correspondingly higher one, except at 40 per cent moisture. But in these experiments, there was only 19 per cent infection at 55°F (about 12°C), as compared to 82 per cent at 85°F (about 29°C). It is possible, that at so low a temperature, some of the spores may not have germinated, and the seedlings, therefore, remained uninfected from the very beginning. However, Gage's [1927] work provides evidence against such a possibility. He found that a majority of the spores of *U. avenae* and *U. levis* had germinated at 60°C, when only a few oat seeds had sprouted.

The slow growth of the young seedlings, at the 55°F soil temperature, would also give ample time for these to become infected. That this is also a factor of importance in the seedling infection has been shown by Brefeld [1890].

Another known factor for the non-infection of the plants could be the constant higher moisture percentage (that is, at all times) as compared to other treatments, but Reed *et al.* [1924] obtained at 10°C, infection percentages as high as 67, 56 and 50 at moisture percentages of 20, 25 and 30, respectively, while in the present experiments, the moisture percentage was around 21 per cent. Thus, there is every likelihood of most of the plants becoming infected at their seedling stages.

Fig. 5. (a) The growth of plants in "8-hour day length" and "16-hour day length". (a) 1½ months after sowing.

Fig. 5. (b) The growth of plants in "8-hour day length" and "16-hour day length". (b) 5 months after sowing.

This low infection at lower temperature may, possibly, be explained on the basis of growth relationship of host and the pathogen. That smutting of the panicle in oats depends upon growth relation of the suscept and the pathogen, even though the former is infected, is supported by the data presented by Gage [1927]. Other evidence comes from studies on wheat bunt (stinking smut), [Redenhiser *et al.*, 1940]. In the field, the low percentage of bunt frequently has been obtained in what appeared to be rapidly growing plants. It is often assumed, that under these conditions, the bunt fungus grew more slowly than the wheat plant and failed to keep pace with the growing point of the shoots.

Reed *et al.* [1924], when working on smuts in oats and sorghum, also remarked that there was some evidence, that factors, which influence the development of the plant may have a bearing upon the appearance of smut in the floral organs, but in a later publication, Reed [1936] reported, that the course of development of smut fungi, after entrance during the period of germination, apparently is not influenced by subsequent growth of the host plant. The latter may grow rapidly or slowly, vigorously or weakly, but the final expression of the smut remains essentially unaffected.

In the case under consideration here, it appears, that it is not the total growth, but the relative growth in a certain period, which may have been responsible for the escape.

That low temperature plays some role in the percentage of infection of oats by smuts is also shown by Taylor and Coffman [1938], who conducted some experiments on the vernalization of certain oat varieties. They found, that vernalization greatly reduced the occurrence of smut in oats. Iogold, had an average of 4·6 per cent smutted panicles as compared with but one smutted panicle in a vernalized row in all three years. No explanation is given by them for their results.

In most cases, the real cause of disease escape, brought about by certain treatments, like low temperatures, is not clearly understood. It is possible that certain metabolic processes of a plant may play some part in inducing resistance to a disease. For example, in the present experiments, there was low respiration and slower growth of plants growing at soil temperature of 55°F during the treatment period. This results in an increase of sugar content of the cells, which besides increasing the thickness of the cell wall, may also decrease the enzymatic activity responsible for dissolving the cell wall to make way for the penetration of the mycelium into the cell. That there is a correlation between resistance and a type of metabolism in the plant has also been indicated by Dickson [1923, 1928]. The seedling blight of wheat and corn (*G. saubinetti*) attacks wheat at low temperature and corn at high temperatures. At low soil temperatures according to this author, the starch of the wheat endosperm is hydrolized much more rapidly than is the protein, with the result, that the seedling is rich in sugar, but poor in nitrogen. The cell wall, therefore, thickens rapidly by the deposit of cellulose material upon the original pectic framework and on that account becomes less susceptible to fungal attack. On the other hand, at higher temperatures both the starch and protein are rapidly hydrolized, the seedling is richer in soluble nitrogen, growth is much more rapid, and the

cell walls remain much longer in the primary pectic conditions. These are thus more susceptible to fungal attack. Corn seedlings, on the other hand, require a higher temperature for growth than wheat seedlings, and thus their behaviour, in relation to temperature, is converse to that of wheat. At high temperatures, favourable to corn, the cell walls of the seedlings are of a resistant and somewhat suberised type, while the modified pectic type of cell wall is produced at low temperatures. It appears, therefore, that certain metabolic processes during the treatment period and relatively rapid growth afterwards, may be responsible for low infection at lower soil temperature in these experiments.

Another interesting result of these findings was the increase in percentage of mortality with increased susceptibility. This is supported by similar results obtained by Bayles *et al.* [1929].

Light

The first visible effect of long day was to shorten greatly the time required for the plant to reach maturity, while the reverse was the case for short day, as compared to the control. Similar results have been obtained by Reed [1938] but whereas in his case, these marked variations in the rate and extent of growth of the oat varieties showed no conspicuous difference in their effect upon the percentage of infected plants (all being equally heavily smutted) there were striking differences in the percentage of infection in the experiment described here.

Other investigations have also shown very striking differences in percentage infection, as influenced by different light durations in some of the diseases (reviewed earlier). Here, the work of Rodenhiser and Taylor may be mentioned. They [1940] found striking differences in percentage infection of bunt, when "Hope" and "Marquis", the two varieties of wheat were exposed to different durations of light. They [1943] also got different results with eight races of stinking smut with two durations of light on "Canis" and "Ulka" wheat varieties. While discussing their results in the light of those obtained by Reed and Lasser, they concluded that the effect of illumination in changing the host reaction to smut is specific for certain hosts and races of the fungi involved. The reason for the different results obtained in these experiments from those of Reed may be explained on the basis of different host reaction to smuts and also different races of fungi involved. The higher infection obtained in 8 hour, "light duration" as compared to 16-hour light duration can be explained on the basis of lower sugar content of the cells in the former, due to the shorter period for photosynthesis. This will decrease the thickness of the cell wall and thereby impose a lesser barrier to the invasion of the fungus mycelium. The decrease in sugar content may also increase the enzymatic activity, which by dissolving the cell wall, may make the entrance of the mycelium into the cell more rapid.

Summary

1. The influence of soil temperature and light upon the infection of Mabel oat variety to smut was studied.

2. Mabel was grown at four different soil temperatures namely, 55°F, control (about 66°F), 75°F and 85°F (with 21 per cent soil moisture).

3. While the percentage of germination was the same in all the treatments, there were striking differences in the percentage of plants reaching maturity. It was 66 per cent in both the 55°F soil temperature and the control, but fell to only 52 and 53 per cent at soil temperatures of 75°F and 85°F respectively (the soil temperature, which also gave higher infection). This is interesting, since it is not only the amount of visible infection, which is increased at favourable temperatures, but also the so called latent or hidden infection, which brings higher mortality.

4. Striking differences were also observed in the percentage of infection in different soil temperatures being highest at 75°F (100 per cent), decreasing both ways. This decrease was more pronounced on the lower side of the temperature than on higher.

5. Two light durations of 8-hours and 16-hours each day (carried out for one and one-half months only) were studied with striking differences in percentage infection at the heading time. Plants receiving 8-hours daylight gave 92 per cent infected plants as compared to 57 per cent in those receiving 16-hour light duration.

6. The importance of growth relationship of host and the pathogen is emphasized. Any factor internal or external, which either increases the growth of the host at a rate more than that of the pathogen or inhibits the proper growth of the fungus even though the host is growing at a normal rate, results in non infection of most of the heads, although otherwise the variety may be highly susceptible.

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STUDIES OF THE ANTHRACNOSE OF LIME TREES IN UTTAR PRADESH

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[with 1 Text Figure.]

ANTHRACNOSE is commonly observed on lime and guava trees which are extensively grown in Uttar Pradesh but the disease has not been studied fully and control measures are not properly known, even though it is worldwide in distribution. An attempt was, therefore, made to study the disease and to find out suitable methods for its control.

Dey [1934] first reported the anthracnose disease on lime trees in U.P., but it has considerably increased since then and has been responsible for the death of numerous growing twigs every year.

Chaudhari [1936] found that it severely affected the lime industry of the Punjab. Asthana [1946] observed the anthracnose of oranges and other citrus plants in the Central Provinces and Berar.

Sunderaraman [1933] found that anthracnose caused heavy defoliation and dropping off of fruits in Coimbatore region. Outside India the trouble has been reported from several other countries. Leach [1952] observed that numerous attacks of epidemic anthracnose greatly injured the cultivation of lime in Trinidad. Klotz [1948] also noted severe die-back of twigs of neval oranges and other citrus fruits in America. Pitman [1919] mentioned that anthracnose was common disease of lemon in Australia. Averna Sacca [1940] also reported that anthracnose fungi caused considerable damage to citrus plants in Brazil and along the coast of Sao Paulo. Agarwala [1955] noticed that high humidity combined with new tender growth and profuse development of flowers favoured the infection in rainy season.

Material and Methods

The material and the method for isolation were similar to those described by Tandon and Agarwala [1954]. The organism responsible for anthracnose of lime trees was found to be *Gloeosporium limetticolum*. Different parts of the orchards containing infected plants were grouped into following series for detailed field trials.

Series I

In this series only the dead twigs, infected in the previous year, were pruned off and the bases of such plants were cleaned to remove the old fallen twigs and the grass. All the debris was burnt. The first pruning of the infected twigs was carried out in June before the new growth could start and another was completed in the last week of July. Fallen leaves were collected regularly and the grass or weeds were not allowed to grow near the trees. These plants were then sprayed with either bordeaux mixture 3 : 3 : 50, 5 : 5 : 50 or peronox 0·33 per cent. These

fungicides were selected after laboratory evaluation of a number of substances including bordeaux mixture 3 : 3 : 50, 4 : 4 : 50, 5 : 5 : 50, peronox 0·22 per cent, 0·33 per cent Diathane 2-78, Paragate, zerlate and Isothane Q-15.

Series II

In another group the fungicides were sprayed as in Series I with hand sprayer on the diseased trees but without removing the dead twigs or the fallen debris near the trees.

In every case the spraying was carried out only on sunny days when there was no chance of rain. In general the plants in the orchard selected for study were sufficiently infected before pruning or spraying. Every plant in the orchard was either severely or moderately infected with *G. limetticolum*. The effect of different treatment on the yield of crops was studied during 1952-53 and 1953-54. The cost of spraying per tree and its effect on the increase of yield was determined. This was necessary for getting some idea about the possible profit due to fungicidal treatment.

Symptoms

The symptoms caused by lime anthracnose organism have been described by Fawcett [1936] and Klotz [1948]. In Uttar Pradesh also the fungus attacks young and tender shoots, leaves and flowers. Infection usually starts from a young stem and commonly advances upto 4-5 inches but occasionally it extends up to 2 feet or more. Side shoots of the current growth also wither or die but water shoots remain unaffected. The dead parts of the twigs or stem assume silvery grey appearance and under suitable conditions of humidity and temperature they develop minute dots of black colour. Older parts of the plants become immune for further fresh attack by this organism. The infection previously developed in young stage may, however, continue to increase. The sharp demarcation of the diseased from the healthy part and their silvery grey appearance are very characteristic (Fig. I).

The disease attacks leaves, petioles, twigs and fruits. The stigmatic surface of the open flowers is also attacked. The infected stigma becomes brown or dark brown in colour and assumes the appearance of normal decay after fertilization but it inhibits the growth of the developing fruit. Further development of the buds depends on the severity of infection. They may die without starting growth, may push out into small rounded fruit and then die (viz. produce mummies) or in less severe cases, the fruit may be produced and only sunken, chocolate coloured circular or irregular spots may be developed on their surface when they attain maturity.

The effect of the disease on the general appearance of the tree can be noticed at any time of the year but the incidence of the disease depends largely on the health of the trees.

Pathogenicity

The method used by Tandon and Agarwala [1954] was used for studying the effect of artificial inoculation on tender green twigs, flowers and leaves of lime trees and it was found that *Gloeosporium limetticolum* was pathogenic and it caused the anthracnose symptoms in the inoculated parts of the plants.

Fig. 1. Infected citrus twig showing sharp demarcation of the diseased from healthy part.

The effect of three applications of the fungicides on pruned and unpruned plants is recorded in Table I.

TABLE I

Effect of bordeaux mixture and peronox on the diseased (pruned and unpruned) plants of lime

Treatment	Per centage of new infection of lime plants	
	Pruned and cleaned	Unpruned and uncleaned
Bordeaux mixture 3 : 3: 50	10	25
,, ,, 5 : 50	7	20
Peronox 0·33 per cent	7	21
Control (without fungicide)	20	38

It is evident from Table I that bordeaux mixture 5 : 5 : 50 or peronox 0·33 per cent greatly reduced the infection. It was observed that pruning and cleaning of the orchard was essential as the disease was not substantially controlled without such operations. It may also be pointed out that the disease was less severe even with one or two applications of the fungicides but the best results were obtained with three applications; hence only the results obtained with three applications have been recorded in Table I. More frequent applications did not improve the condition.

Inspite of the vigorous efforts to eradicate the disease completely, it was not possible to do so as the disease appeared in some cases. Shear and Wood [1931], Wardlaw *et al.* [1939], Asthana [1946], Adam *et al.* [1949] and Tandon and Agarwala [1954] have pointed out that the species of Collectotrichum and Gloeosporium were able to remain in a dormant or quiescent condition in the leaves, stems and fruits of a wide range of host plants. It appears that the absence of complete control may be due to the presence of mycelium inside the host before the fungicides were applied. Inspite of the implication (living of the organism in dormant stage inside host tissues) involved, fungicidal spray and pruning, etc. on the infected trees was beneficial as their application could considerably reduce the percentage of new infection. It was, however, clear that none of the treatment could control the disease fully.

Cost of spraying

The cost of spraying was calculated on the basis of 3 gallons per tree. Depreciation at the rate of 10 per cent per annum was allowed on the machinery used for spraying. It was determined that the annual cost of three treatments with the recommended strengths of bordeaux mixture (including all the labour charges for pruning, etc.) was Rs. 1/6/3 for each lime tree. The yield increased by 33 per cent [Agarwala 1955] and due to this the average profit per treated plant was Rs. 5/14/0.

1. All the infected twigs, leaves or dried mummies either attached to the plants or fallen on the ground should be regularly collected and burnt. The process may be repeated at least 3-4 times during the rainy season.

2. The trees should be sprayed thrice during the rainy season, with 5 : 5 : 50 bordeaux mixture or 0·33 per cent peronox. It will be desirable to maintain a protective cover of the suggested fungicide throughout the period of new growth of the twigs and leaves. This can be possible by starting the first spraying in the last week of June, the second during the rainy season and the third after the rainy season.

SUMMARY

The detailed symptoms of the anthracnose disease of lime trees caused by *Glocosporium limetticolum* have been described and it has been established that the organism is pathogenic. It could readily attack the young twigs, leaves, flowers and buds.

Three applications of 5: 5: 50 bordeaux mixture or 0·33 per cent peronox were found to be suitable for controlling the disease. Other necessary recommendations have been suggested for preventing the spread of the disease.

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A COLD PERCOLATION METHOD FOR RAPID GRAVIMETRIC ESTIMATION OF OIL IN SMALL QUANTITIES OF OIL SEEDS

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In continuation of earlier work on the determination of yield and iodine value of oil in small quantities of oilseeds [Chopra *et al.*, 1952 ; Sethi *et al.*, 1953 ; Kartha *et al.*, 1955] a new cold percolation method of determining oil content in small quantities of seeds has now been worked out. The technique of grinding oilseed with excess of dehydrating agent and sand for preparing it for extraction appears to have been first reported by Biazzo [1921]. Biazzo recommended grinding enough of the seed sample to give 2 gm. of oil with three times its weight of anhydrous copper sulfate and excess of sand at room temperature, putting it into a thimble and then extracting it with ether in a soxhlet. This treatment gave a friable, porous mass which could be readily and completely extracted. Maslekiov [1930] studied this further and stated that the usual method of mixing the sample with sand to increase the porosity of the material is not sufficient because fine vegetable particles are soon separated by the motion of the solvent and clog the pores formed by the sand. When the finely powdered material is mixed with a soluble salt like sodium chloride, sodium sulfate or copper sulfate and an intimate mixture of this prepared by making a smooth paste of the mixture by adding a small quantity of water and then drying it, the fine vegetable particles are adsorbed on the surface of the salt crystals and the whole forms a stable porous mass. The same results will be obtained when the seed contains small amount of moisture, simultaneously dehydration of the seed will also take place. Wolfgang Leithe [1934] and Geddes and Lehberg [1936] have used the technique of grinding the seed with excess of anhydrous sodium sulphate and sand in the presence of a limited amount of high boiling solvent like dichlorobenzene, etc. and filtering through filter-paper for refractometric determination of oil content of specific seeds. Ready filtration of oil extract could be effected under the circumstances.

Leithe [1934] has further reported that when the seed is pulverised in a mortar with sand and anhydrous sodium sulphate, shaking with a gasoline fraction of B. P. 90-100°C, two minutes are enough for the complete extraction of oil. In view of this observation and the suggestion of Maslekiov [1930] that the fine seed particle get adsorbed on the surface of the anhydrous salt crystals and or not easily dislodged by flowing solvent, it appeared interesting to investigate the cold percolation of seed after grinding with anhydrous sodium sulphate and glass powder (in place of sand) with a view to see how far this can be adapted for estimation of oil in small quantities of seeds. If successful this will lead to two substantial improvements ;

(1) avoidance of filtration through filter paper or sintered glass funnel (this effects a large saving of time and also reduces possible error introduced by evaporation of solvent during filtration).

(2) the complete extraction can be done with a comparatively small volume of solvent which can be conveniently evaporated off in an oven in an open dish and weight of residue determined.

Experimental

The following experimental procedure was adopted in the present studies :

About 0·3 gm. of seed is accurately weighed and transferred to a porcelain or glass mortar. Two gm. each of glass powder (Pyrex glass washed with concentrated hydrochloric acid) and anhydrous sodium sulphate are added and the mixture reduced to fine powder. The mixture is transferred to a small glass percolator 20 cm. long and 15 cm. in diameter (this is prepared by drawing a taper at one end of a glass tube 1·5 cm. in diameter and inserting a perforated glass plate just above the taper) and packed over a layer of coarsely powdered anhydrous sodium sulphate (0·25-0·314 inches thick) supported on a thin wad of cotton wool over the perforated glass plate. The mortar and pestle are washed twice with 0·5 gm. of anhydrous sodium sulphate and the washings are also packed over the seed powder. Finally the mortar and pestle are washed with 3-4 cc. of freshly distilled petroleum ether B.P. 70-90°C and this transferred to the packed meal powder. This initial 3-4 cc. of solvent serves to wet the mixture. This is allowed to remain as such for five minutes and then percolation started by adding measured quantity of solvent on the top of the column. The first lot of 7cc. is collected in a weighed dish containing four one-inch-square-strips of filter paper. The second lot of 3 cc. is collected in another similar dish. The solvent is evaporated by keeping the dish in an oven at 96-100°C for half an hour. It may be specially pointed out that in the absence of requisite amount of filter paper a constant weight is not reached even within two hours when appreciable amount of oil is present and petroleum ether B.P. 70-90° C is used, while when the above mentioned area of filter paper is used (4 sq. in. for maximum of 0·2 gm. of oil); a constant weight is reached within 15-20 minutes.

Results

The results of this procedure applied to some 15 varieties of seeds are given in Table I. It is seen from this that extraction of oil is virtually complete in the first seven cc. in practically all cases : only in a very few cases is any weighable amount of oil was left in the second dish. The cold percolation method as described above can hence be successfully used in the extraction of oil in the oil seeds : the amount of percolate to be obtained for a ca. 0·3 gm. specimen need not be more than 10 cc. at most : 7cc. will be quite satisfactory when known varieties are used.

The advantages of the method are (1) that it is rapid (2) that it is gravimetric and does not in any way fluctuate with changing characteristics of different specimens of seed as in the refractometric method, (3) that it requires only small amounts of

solvent and seeds, (4) passing of the extract containing ' fines ' through filter paper is entirely avoided and, (5) since the weight of all and not an aliquot part is obtained, the accuracy reached is raised to maximum.

In view of the fact that the whole of the oil in the seeds under experiment is isolated and weighed, it appeared interesting to investigate what is the accuracy obtainable if ca. 0·1 gm. of seed is used instead of the 0·3 gm. For this two series of experiments were run using ca. 0·1 and ca. 0·3 gm. each of the same seed : however in case of small seeds the seed sample was carefully cleaned, washed with water, and dried, because a small error in the sampling can produce appreciable error in oil content when weight of sample is very small. The comparative results obtained are given in Table II and show that when due care is taken accurate results can be obtained on a small sample as 0·1 gm. of seed sample with an ordinary analytical balance and when a microbalance is available even on smaller samples.

The significance of the present results is of two kinds. First accurate oil estimation can be effected even when small quantities of seeds only are available and second is the fact that this improvement makes it feasible for us to determine the distribution of fat in different portions of the same fruit seed or other fat depot in instances where collection of large size samples (say more than 0·2-0·3 gm.) is extremely difficult if not impossible.

A comparison of the present technique with the rapid refractometric technique of Zeleny [1937] shows the following advantages :

(1) Refractometric method requires ca. at least 5 gm. of the finely divided seed. Present technique can be applied with as small as say 100 mg. of seed (still smaller quantities when microbalance is available).

(2) Present method is not affected by variations in refractive index of different samples and can be directly applied to all oilseeds. Elaborate preliminary work is necessary before refractometric methods can be applied to different seeds : even then the refractive index of oil in every specimen of seed to be analysed has to be determined separately.

(3) Time taken for determining oil content by present method is only nearly the same as that taken for extracting and determining the refractive index of the samples in the refractometric method : one technician can do, not less than 4 determinations very 2 hours.

(4) 10-15 cc. of petroleum ether is all the solvent that is required by the present method ; no expensive equipment or solvent are required.

(5) Necessity for the filtration through filter paper or sintered glass funnel or by centrifugation is entirely avoided in the present method.

The method is now being used for routine determination of the oil content of various seeds in the Institute.

Acknowledgment

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TABLE I

Cold percolation of oil seeds with petroleum ether

(Weight of seed 0·3-0·5 gm.)

Serial No.	Name of seed	Replicate	Weight of seed (gm.)	Weight of 1st dish (gm.)	Oil from 2nd dish (gm.)	Percentage Oil	
						1st dish	2nd dish
1	Groundnut Oil	1	0·3058	0·1458	0·00002	47·6	0·06
		2	0·3055	0·1404	0·0003	45·9	0·09
2	*Til* seed white (1955) specimen	1	0·5230	0·2686	..	51·3	..
		2	0·5032	0·2681	..	52·1	..
3	Safflower seed N. P. 1 variety	1	0·3320	0·0871	..	26·2	..
		2	0·3754	0·0944	..	25·2	..
4	Linseed No. 1	1	0·3174	0·1234	0·0006	38·8	0·19
	(1952) specimen	2	0·3040	0·1134	0·002	37·2	0·06
5	Poppy seed	1	0·3000	0·1346	..	44·8	..
	(1952) specimen	2	0·3100	0·1400	0·0002	45·1	0·06
6	Tobacco seed (1952) specimen	1	0·3128	0·1192	..	38·1	..
		2	0·3528	0·1390	0·0002	39·4	0·06
7	Linseed N. P. 12	1	0·3122	0·1106	0·0002	35·4	0·06
		2	0·3054	0·1110	0·0006	36·3	0·19
8	Barssica capestria Var Ren T 22	1	0·3304	0·1420	0·0004	42·9	0·12
		2	0·3278	0·1409	0·0005	43·0	0·15
9	Melon	1	0·3099	0·1305	0·0006	42·09	0·19
		2	0·3186	0·1336	0·0006	41·9	0·18
10	Walnut.	1	0·3191	0·2151	0·0008	67·4	0,25
		2	0·3123	0·2148	..	68·9	..
11	Water melon	1	0·3024	0·1516	0·0004	50·1	0·13
		2	0·3230	0·1580	0·0008	48·9	0·24
12	Cashewnut	1	0·3086	0·1380	0·0002	44·8	0·06
		2	0.3198	0·1490	..	46·5	..
13	*Khira*	1	0·3016	0·1366	0·0007	41·9	0·23
		2	0·3020	0·1350	0·0002	45·0	0·06
14	Almond	1	0·2990	0·1662	0·0005	55·5	0·19
		2	0·3000	0·1649	0·0006	54·9	0·02
15	*Erythrina indica*	1	0·5006	0·0624	0·0006	12·47	0·11
		2	0·4946	0·0663	0·0009	13·4	0·14

TABLE II

Cold percolation of oil seeds with petroleum ether

(Weight of seed ca. 0·1 and ca. 0·3 gm.)

Serial No.	Name of seed	Replicate	Weight of seed (gm.)	Weight of 1st dish (gm.)	Oil from 2nd dish (gm.)	Percentage Oil	
						1st dish	2nd dish
1	*Til* seed (fresh) (1955) specimen	1	0·1026	0·0586	0·0006	57·14	0·58
		2	0·1066	0·0626	..	58·73	..
		3	0·3000	0·1764	..	58·8	..
		4	0·3090	0·1814	..	58·67	..
2	*Til* seed (Old) (1952) specimen	1	0·1044	0·0548	..	52·49	..
		2	0·1020	0·0528	..	51·87	..
		3	0·3074	0·1612	..	52·44	..
		4	0·3008	0·1564	..	52·00	..
3	*Brassica campestria* Var taria T22 (1952)	1	0·1016	0·0432	0·0002	42·52	0.19
		2	0·1036	0·0446	..	43·07	..
		3	0·3020	0·1290	0·0001	42·72	0.03
		4	0·3021	0·1268	0·0002	41·1	0.06
4	Mustard seed Rai variety (1952)	1	0·1088	0·0382	..	35·12	..
		2	0·1067	0·0380	..	35·6	..
		3	0·3065	0·1070	0·0002	34·91	0·06
		4	0·3070	0·1080	0·0002	35·18	0·06
5	Linseed (1952) specimen	1	0·0982	0·0406	..	41·34	..
		2	0·0974	0·0400	..	41·07	..
		3	0·2982	0·1204	0·0002	40·37	0·06
		4	0·2983	0·1192	0·0002	39·95	0.06
6	Linseed No. 294 52	1	0·1034	0·0360	..	34·2	..
		2	0·1016	0·0352	0·0004	34·05	0·3
		3	0·3030	0·1039	..	34·3	..
		4	0·3072	0·1090	..	35·48	..

TABLE II—*contd.*

Cold percolation of oil seeds with petroleum ether

(Weight of seed ca. 0·1 and ca. 0·3 gm.)

Serial No.	Name of seed	Replicate	Weight of seed (gm.)	Weight of 1st dish	Oil from 2nd dish	Percentage Oil	
						1st dish	2nd dish
7	Poppy seed (1952) specimen	1	0·1036	0·0488	..	47·10	..
		2	0·1007	0·0480	..	47·66	..
		3	0·3060	0·1482	..	48·42	..
		4	0·3042	0·1480	..	48·64	..
8	Tobacco seed	1	0·1060	0·0314	..	29·62	..
		2	0·1030	0·0310	..	30·0	..
		3	0·3026	0·0884	0·0003	29·2	0·00
		4	0·3036	0·0864	0·0002	28·5	0·06
9	Tobacco seed (1952) specimen	1	0·1090	0·0456	..	41·7	..
		2	0·1074	0·0440	..	40·95	..
		3	0·3064	0·1251	0·0002	40·82	0·06
		4	0·3068	0·1214	0·0002	39·77	0·06
10	Melon	1	0·1043	0·0432	..	41·4	..
		2	0·0858	0·0372	..	43·2	..
		3	0·3013	0·1248	..	41·1	..
		4	0·2832	0·1196	..	42·1	..
11	Water melon	1	0·1127	0·0499	..	44·2	..
		2	0·1182	0·0510	..	43·65	..
		3	0·3170	0·1394	..	43·9	..
		4	0·3092	0·1353	..	43·7	..
12	*Kaju*	1	0·1034	0·0434	..	41·98	..
		2	0·1032	0·0429	..	41·58	..
		3	0·3018	0·1250	..	41·42	..
		4	0·3082	0·1320	..	42·7	..
13	Almond seed	1	0·1062	0·0582	..	54·8	..
		2	0·1074	0·0566	..	52·7	..
		3	0·3022	0·1618	..	53·44	..
		4	0·2018	0·1679	..	54·9	..

to publish the results. They also thank Dr S. P. Raychaudhuri, Head of the Division of Chemistry, for his kind interest in the work.

Summary

It has been reported in the literature that if an oilseed is ground with excess of sand and an electrolyte like Na_2SO_4 NaCl, $CuSO_4$, etc. the particles of seed get adsorbed in the salt and are not subsequently dislodged by motion of solvent during subsequent extraction. If this adsorption is sufficiently strong, then under suitable circumstances, filtration of the oil solution can be avoided resulting in a considerable saving of time and manipulation in estimation of oil yield.

This possibililty was investigated and it was found that when a ca. 0·3 gm., of seed is ground well with 2 gm. each of glass powder and anhydrous sodium sulphate, packed in a small glass percolator over a bed ($\frac{1}{4}$ inch thick) of anhydrous sodium sulphate supported on a wad of cotton wool, and the mixture percolated with petroleum ether or other solvent, a clear percolate was readily obtained thus eliminating all necessity to filter the extract. It was also found that practically the whole of the oil present was removed in the first 7-8 cc. of percolate ; subsequent 3-4 cc. of percolate containing almost no oil.

It was also found that when a solution of oil in petroleum ether B.P. 70-90°C is evaported in an oven at 95-100°C in presence of filter paper (4 one inch squares of filter paper for every 0·2 gm. of oil present) the evaporation is extremely rapid, and the last traces of solvent are removed in 20-50 minutes at most. If the evaporation is done without the filter paper, the last traces of solvent will be removed only after about 2-3 hours or even more.

Based on the above results a cold percolation method has been developed in the laboratory whereby the yield of oil in a 0·3 gm. specimen of seed can be determined in about one and a half hours without any costly equipment or chemicals or laborious manipulation. When due care is taken about preparation of sample, the method can be applied successfully to as small as 0·1 gm. of seed.

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A STUDY OF THE ENDOSPERM AND EMBRYO IN *MANGIFERA* L.

By R. C. Sachar and R. N. Chopra

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(With Plate I-VII)

POLYEMBRYONY in mango was first recorded by Schacht [1859 : quoted in Arndt. 1935]. Strasburger [1878] and Cook [1907] concluded that the extra embryos in mango were of nucellar origin. The latter noted as many as 8 embryos arising within a single seed, but failed to ascertain whether or not the "strong" embryo came from the fertilized egg. Mendiola [1926] from the Philippines reported that 10 or even 30 seedlings may grow from a single seed of the *Carabao* or *Pico* variety.

Belling [1908] in *Florida No.11* and Juliano [1934] in the *Strawberry* mango found that the zygote fails to develop and all the embryos in a seed are of nucellar origin. Juliano and Cuevas [1932] and Juliano [1937], in the *Pico* and *Carabao* varieties respectively, showed that the zygote usually persists and forms a sexual embryo, but sometimes it may degenerate in which case all the embryos in the seed are of nucellar origin. Juliano [1937] has emphasized the difficulty in establishing whether seedlings arise from sexual or asexual embryos in polyembryonic seeds.

While some work has been done on foreign varieties [Juliano. 1934. 1937 ; Juliano and Cuevas. 1932] in order to determine the behaviour of the zygote and nucellar cells and to utilize this knowledge in the improvement and propagation of the mango, practically no literature[1] in this line is available on the Indian varieties. Sen and Mallik [1940] have stressed the necessity for investigating the behaviour of the fertilized egg in the mono as well as the polyembryonic varieties. Such information would greatly facilitate the attempt to improve the Indian mango by hybridization. Varieties producing only nucellar embryos should be known so that they could be used as root stocks, thus ensuring uniformity in mango production.

Material and Methods

Preserved material of several varieties of *Mangifera indica* and one of *M. oleracia* was obtained from different parts of India, Ceylon and Philippines. The synopsis is given below[2] :

Variety	Source	Name of collector
Mangifera indica		
1. *Paho*	Manila, Philippines	E. Quisumbing
2. *Colampan*	Vaddukoddai, Ceylon	T. J. Koshy
3. *Chempattan*	do.	T. J. Koshy

[1] Maheshwari [1934] published a preliminary note on some aspects of the embryology of a variety from Allahabad, the preparation for which had been made by the late Dr. W. Dudgeon.

[2] Our thanks are due to all those who very kindly provided the material for the present study.

Variety	Source	Name of Collector
4. *Olour*	Coimbatore	K. V. Krishana moorthy
5. *Peter*	Kallur, Mysore	R. Narayana
6. *Bangalora*	do.	R. Narayana
7. *Desi*	New Delhi	R. C. Sachar
8. *Rahagir*	Kallur, Mysore	D. M. Ramaiah
9. *Pairie*	Poona	S. P. Capoor
10. *Higgins*	Laguna, Philippines	J. M. Capinpin
11. *Cambodia*	do.	J. M. Capinpin
12. *Mundappa*	Chepauk, Madras	T. S. Sadasivan
13. *Neelum*	do.	T. S. Sadasivan
14. *Rumani*	do.	T. S. Sadasivan
15. *Malgoba*	do.	T. S. Sadasivan
16. *Imampasand*	Gudivada, Andhra	B. S. M. Dutt
17. *Bauginapalli*	do.	B. S. M. Dutt
18. *Tiyyamamidi*	do.	B. S. M. Dutt
19. Var. from Singapore	Singapore, University of Malaya	R. E. Holttum
Mangifera odorata	do.	R. E. Holttum

The material was dehydrated and imbedded according to the customary methods. In older ovaries the ovules were dissected out before running them through the alcohol-xylol series. Sections were cut at 12 to 15 microns and stained with Heidenhain's haematoxylin as well as safranin and fast green. Both methods were satisfactory. Older ovules were also dissected under a binocular microscope and the embryos stained with acetocarmine.

Endosperm (Plate I)

The endosperm is of the nuclear type [Juliano and Cuevas, 1932 ; Maheshwari, 1934 ; Juliano, 1937]. Free nuclear divisions continue and a considerable number of nuclei is produced before the zygote undergoes its first division. The nuclei are imbedded in the peripheral layer of cytoplasm (Fig. 1) and show a great variation in size. In some embryo sacs the nuclei in the micropylar end are smaller than those of the chalazal end, while in others large and small nuclei are irregularly distributed (Fig. 2). In still other embryo sacs the nuclei in the micropylar region were found to be more conspicuous because of their larger size or more commonly their hypertrophied nucleoli (Figs. 3 and 4).

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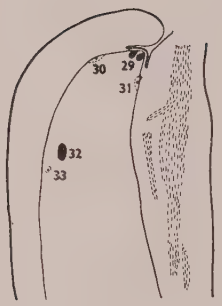

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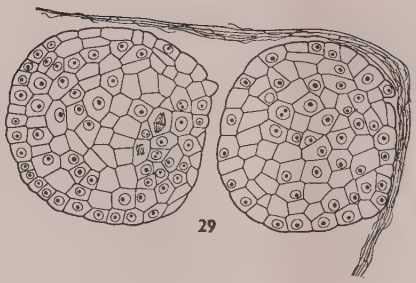

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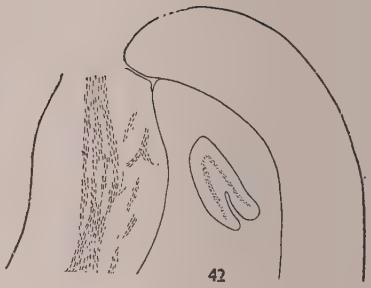

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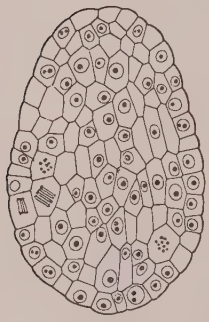

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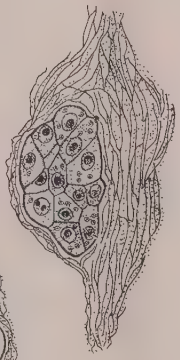

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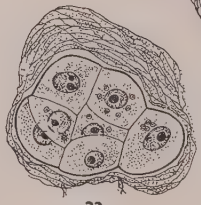

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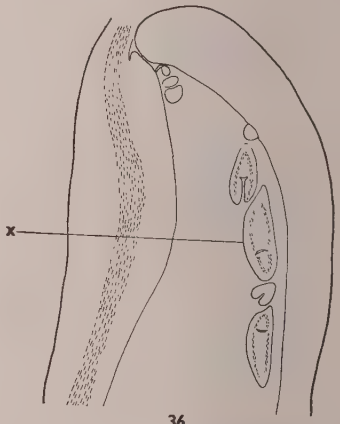

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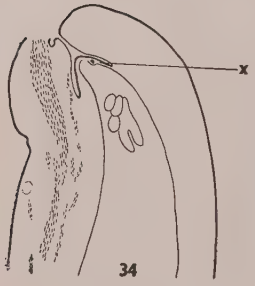

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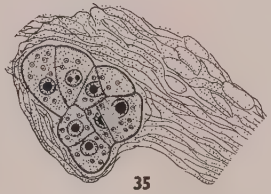

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Simple growth may account for the larger nuclear size (Fig. 2), but nuclear fusions are also common. In the latter case they have an irregular outline and possess nucleoli of varying number and size (Figs. 5-7, 10-13, 14-19). Both normal and polyploid nuclei multiply by mitotic divisions (Figs. 8 and 9).

One preparation of variety *Paho* showed a hemispherical cytoplasmic aggregation at its chalazal end (Fig. 20) which contained several nuclei. This structure may be referred to as an endosperm vesicle or nodule (Fig. 21). A search for similar structures in other varieties yielded only negative results. Nodule formation has been reported in plants like *Musa errans* [Juliano and Alcala, 1933], *Impatiens roylei* [Dahlgren, 1934], *Capsella bursa pastoris* [Maheshwari and Sachar, 1954] and *Cocos nucifera* [Cutter *et al.*, 1955], but their significance has so far not been clearly understood.

Wall formation starts in the micropylar part of the embryo sac along the periphery and later extends towards the centre. The lower part of the embryo sac retains its free nuclear condition for a considerable length of time (Fig. 27), but the whole of the endosperm finally becomes cellular. The cells are usually uninucleate (Fig. 22), but they may also show a multinucleate condition (Figs. 23 and 25). This is chiefly due to the incorporation of more than one nucleus at the time of wall formation. The nuclei in such cells may later fuse to form polyploid masses (Figs. 24 and 26). Along the periphery of the embryo sac the endosperm cells undergo rapid divisions, and are comparatively smaller and more densely protoplasmic than the centrally placed cells, which are larger and highly vacuolated. In later stages the rapidly growing embryos begin consuming the endosperm tissue.

Embryo

Polyembryonic varieties

Var. Paho (Plate II) : A number of deep-seated nucellar cells become richly cytoplasmic during post-fertilization stages. They show numerous starch grains, and undergo repeated division before the resultant masses enter the embryo sac cavity (Figs. 30, 31, 33 and 35).

The adventive embryos usually arise near the micropylar end, but they may also develop on the sides up to the middle of the embryo sac (Fig. 28). The number of embryos in different ovules usually varies from 2 to 9. Embryo formation occurs at different times and a considerable range of developmental stages may be seen in a single ovule (Figs. 28-35). Four among the eight embryos in Fig. 36 have well developed cotyledons while the rest are at the globular stage. Well developed embryos may be observed in proximity of densely cytoplasmic nucellar cells which have not yet divided.

In one ovule five embryos were seen (Figs. 37-41) one of which showed three cotyledons (Fig. 38). This might be explained as being due to fusion of two embryonic masses or splitting of one of the cotyledons of a normal embryo.

All the seeds are not polyembryonic. In two cases a single embryo was observed (Fig. 42).

The zygote could not be traced due to lack of younger stages. If at all it develops, its identification is difficult, because adventive embryos are found almost in the same position. Since sexual and asexual embryos are indistinguishable from one another at the globular stage, it is difficult to say how often an embryo is produced by the zygote.

Var. Olour (Plate III) : It is a highly polyembryonic variety. The development of adventive embryos is initiated after a number of free endosperm nuclei have been formed. The zygote could be seen in early post-fertilization stages, but was not traceable in older ovules.

The nucellar cells destined to develop into adventive embryos are confined to the micropylar end close to the embryo sac cavity (Fig. 43). In some ovules the number reaches up to 40 or more. They are situated very close to one another and are full of starch grains (Fig. 44). The dense cytoplasm gives rounded appearance and becomes surrounded by a new wall. These cells then divide forming embryonic masses which gradually crush the surrounding nucellar tissue and enters the embryo sac cavity.

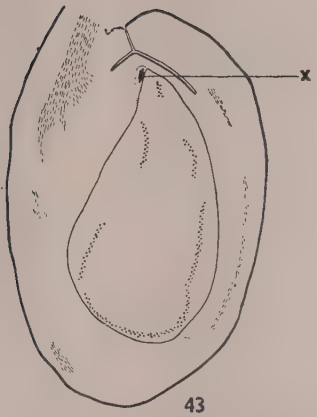
A study of slightly older stages showed that the number of developing embryos usually ranges from 6 to 14. As their development begins at different points of time, various stages of embryogeny can be seen in the same embryo sac. In one ovule for example, there were all gradations from a small globular embryo to one with well developed cotyledons (Fig. 46). A great variation of size and shape also exists. Some are small while others of the same age are very large ; some embryos are symmetrical while others are asymmetrical (Figs. 45 and 46).

The embryos exhibit varying degrees of fusion, which occurs maninly in the region of the radicle (Figs. 45 and 46). It is this feature which is probably responsible for the appearance of seedlings with multiple shoots, but only one tap-root. Such seedlings have been recorded in *Bambai*, *Langra* and *Fazli* [Sen and Mallik, 1940], but no developmental study has yet been made.

Sen and Mallik [1940] performed some dissections and germination tests on mature seeds of *Olour*. Of the 23 seeds, 5 showed only 1 embryo, 6 had 2, 2 had 3, 9 had 4 and 1 had 5 embryos. In another set of 11 seeds only one seedling was produced from each seed.

Var. Cambodia[1] (Plate IV): In this the zygote degenerates and sexual embryo is absent (Fig. 48). Some of the nucellar cells lying close to the embryo sac cavity become very prominent due to their denser contents and larger size (Figs. 47-50). Their contents round off, and after that active divisions begin. The resulting masses

[1] Prof. Jose M. Capinpin, who sent the material, writes that var. *Cambodia* and *Higgins* are introduced from India.



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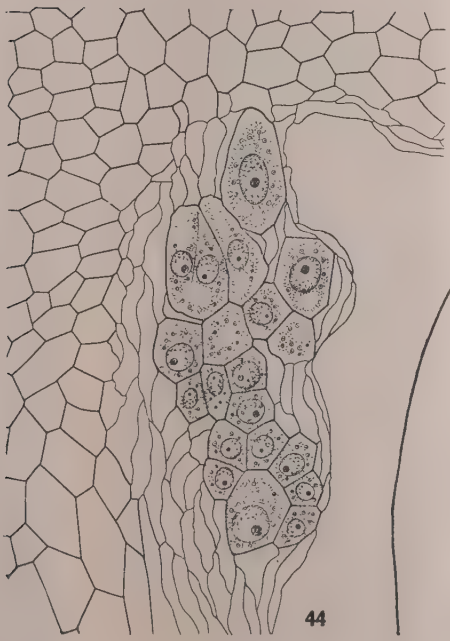

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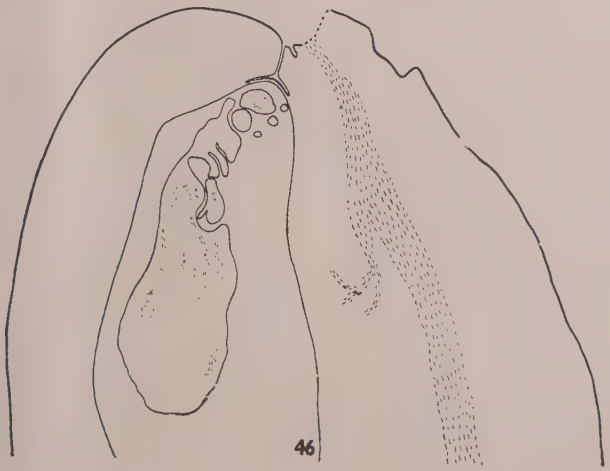

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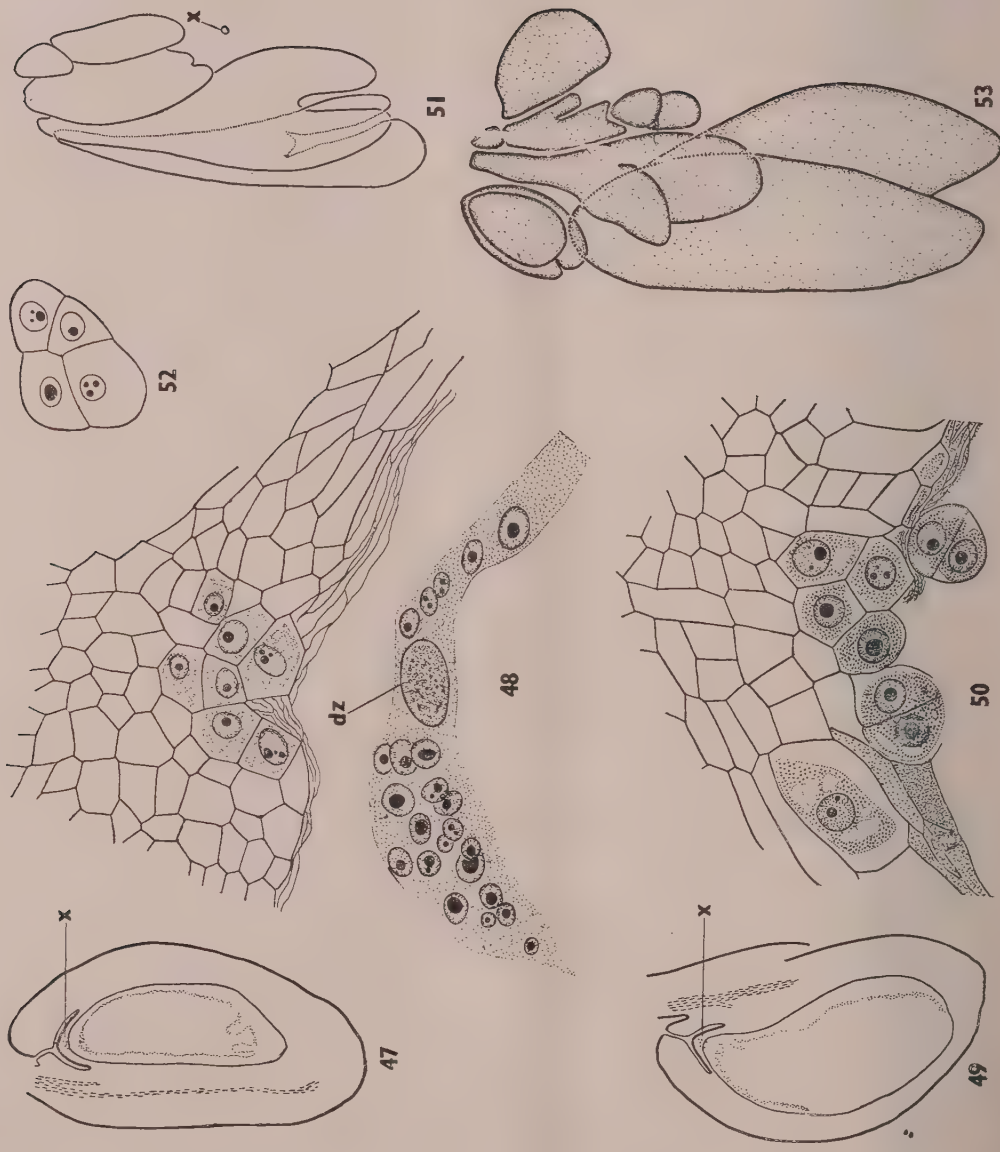
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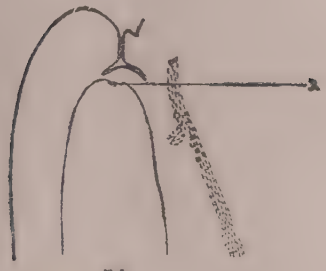

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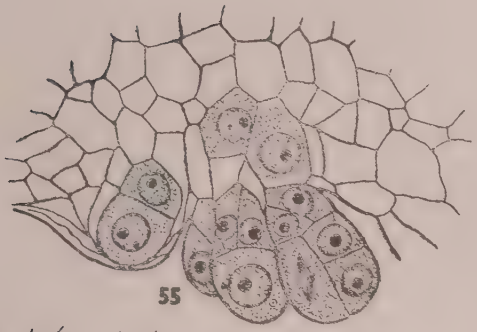

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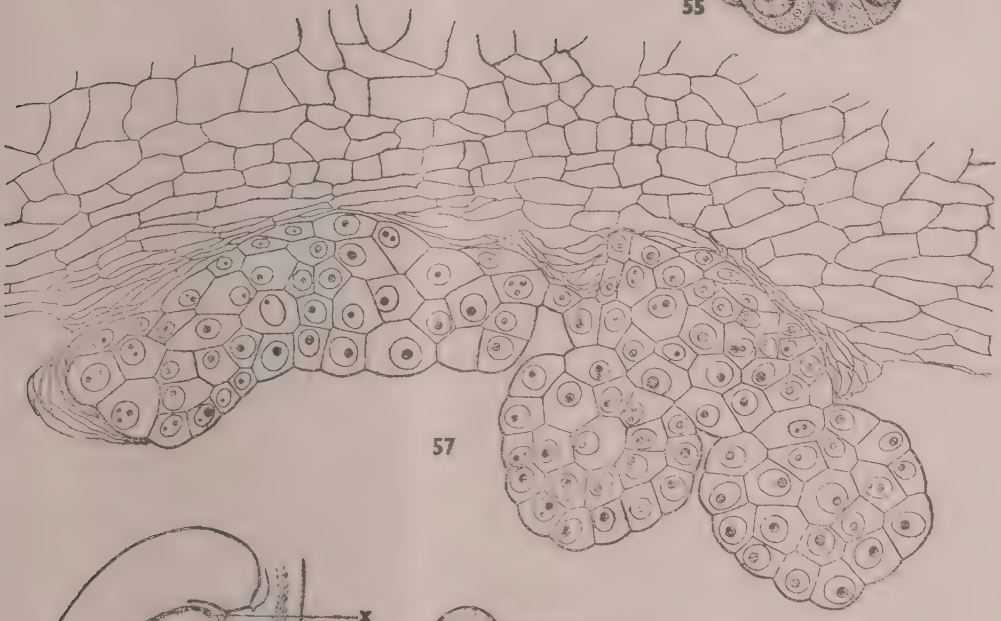

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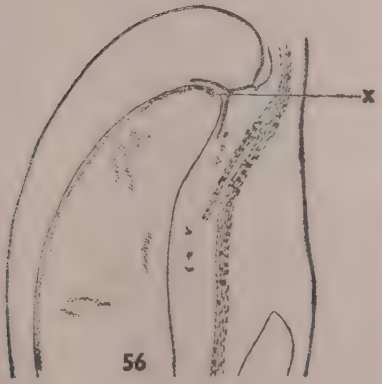

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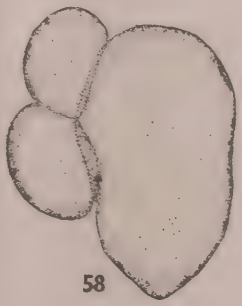

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make their way into the embryo sac cavity by crushing the surrounding cells. Individual cells sometimes protrude into the embryo sac before undergoing division (Fig.50). Usually there are 4 to 9 embryos of varying size, shape and age (Figs. 51-53).

Var. Higgins[1] (Plate V) : Several adventive embryos arise at the micropylar end (Figs. 54-57).

Since several preparations showed a degenerating egg, it seems likely that all the embryos are of nucellar origin. The total number of embryonic groups ranges from 3 to 9 (Figs. 58, 59), but may even reach up to 12. The number of embryos reaching maturity could not be determined as no mature seeds were available.

Var. from Singapore[2] : This variety also exhibited polyembryony. The number of embryos varied from 3 to 6, but some of the seeds had only one embryo. The sexual embryo was indistinguishable from the adventive embryos.

Monoembryonic varieties (Plate VI)

A zygotic embryo has been observed in the monoembryonic varieties, *Neelum*, *Tiyyamamidi*,*Bauginapalli*, *Rumani*, *Bangalora*, *Rajagir*, *Peter*, *Pairie*, *Chempattan*, *Colampan* and *Desi*. The development of the embryo in *Desi* is as below : The zygote remains in a resting state and divides after hundreds of endosperm nuclei have been produced. The first division is followed by a transverse wall after which the apical cell divides vertically forming a 3-celled proembryo (Figs. 60 and 61). The basal cell then enlarges and divides by a vertical partition (Fig. 62). A similar course of development has been observed in *Peter*, *Tiyyamamidi* and *Bangalora*. Like the adventive embryos described before, the young proembryos of these varieties are often filled with abundant starch. Derivatives of both the apical and basal cells of the 2-celled pro-embryo contribute to the formation of the embryo proper (Figs. 63-67), no suspensor is organized.

In some varieties the fate of the zygote remains doubtful due to lack of sufficient material. The younger ovules of *Imampasand* showed a degenerating egg, but in slightly older ones neither the egg nor any prominent nucellar cells could be traced. It seems probable that adventive embryos develop in later stages, but nothing can be said definitely without examining more material of the proper age. In *Malgoba* only very early post-fertilization stages could be studied. These showed a zygote, which at times was accompanied by a degenerating synergid. In one case the zygote was not traceable, but some of the nucellar cells at the micropylar end were more prominent than the rest. The fate of zygote and whether adventive embryos develop or not is difficult to estimate at present. The available *Mundappa* material showed early post-fertilization stages. In one preparation a single detached globular embryo was observed. The zygote often showed two nucleoli and seemed to remain fairly healthy even after a good many endosperm nuclei had been formed. Apparently the zygote persists, but adventive embryony is not ruled out.

[1]See page 222.

[2] Prof. R. E. Holttum (in a personal communication to Prof. P. Maheshwari) writes that there is no local name for this variety of *M. indica* and nothing is known about the history of the tree from which the material was collected.

Mangifera odorata (Plate VII)

Some of the nucellar cells may become prominent at a very early stage (Figs. 68 and 69). The zygote invariably shows signs of degeneration even before the primary endosperm nucleus divides. Thus all the embryos present in the seed are of nucellar origin.

The plasma-rich cells differentiate at the micropylar end of the embryo sac (Figs. 69 and 72). Some of them arise close to the embryo sac cavity (Fig. 69), while others develop deep within the massive nucellar tip (Figs. 70 and 71). The same ovule may show some embryonic masses projecting into the emryo sac cavity, while others are still imbedded in the nucellar tissue (Figs. 72 and 73).

The cells destined to develop into adventive embryos show dense cytoplasm often filled with starch grains (Figs. 69 and 71). The divisions leading to the formation of globular embryo do not follow any regular sequence. The general mode of differentiation and development is similar to that in the polyembryonic varieties of *M. indica*.

The number of embryonic masses varies from 2 to 8 (Fig. 74). Most of the preparations examined by us showed only globular embryos, which made it impossible to estimate the number of embryos attaining maturity. Only one ovule was seen which had two well developed but unequal embryos (Fig. 75).

Discussion

The phenomenon of adventive embryony is known in many angiosperms, and its occurrence in mango has been recorded since a long time. It is interesting to note that within the same species *Mangifera indica* polyembryony is at a varietal level i.e., all the varieties do not exhibit this phenomenon. Some are strictly monoembryonic, others show a gradual tendency towards polyembryony, and still others are known to contain as many as 30 embryos.

The present study is based on 19 varieties of *M. indica* and one of *M. odorata*. Of these, five varieties of *M. indica*, viz. *Paho*, *Olour*, *Cambodia*, *Higgins* and an unnamed variety from Singapore are polyembryonic. *M. odorata* also shows polyembryonic condition. The remaining varieties of *M. indica* showed a single embryo. This originates from the zygote in *Desi Rajagir*, *Chempattan*, *Colampan*, *Peter*, *Tiyyamamidi*, *Banginapalli*, *Neelum*, *Rumani Bangalora* and *Pairie* but in *Imampasand*, *Malgoba* and *Mundappa* its exact origin could not be traced.

It would be worthwhile to discuss the behaviour of the zygote in some of the polyembryonic forms. In a study of *Pico*, Juliano and Cuevas [1932] write "The zygote in all probability gives rise to a larger and far more developed embryo in the sac—Its development is much ahead of that of the other embryos". In one case they observed a degenerating zygote. From this it was concluded that var. *Pico* is on its way to total sterilization, a condition already attained in *Florida No. 11* [Belling, 1908]. Two years later, Juliano [1934] reported that in *Strawberry* the zygote fails to develop, and all the embryos are nucellar. In *Carabao* the zygote shows signs of degeneration in about 50 per cent of the ovules, while in others it is seemingly

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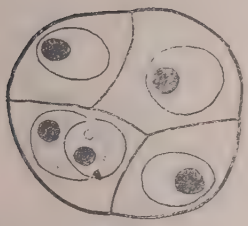

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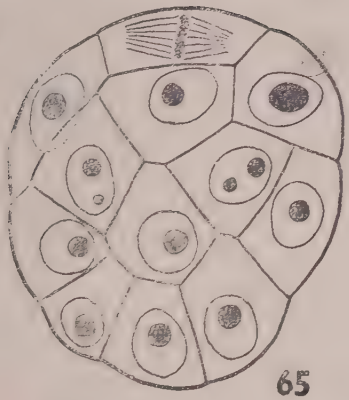

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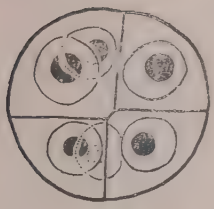

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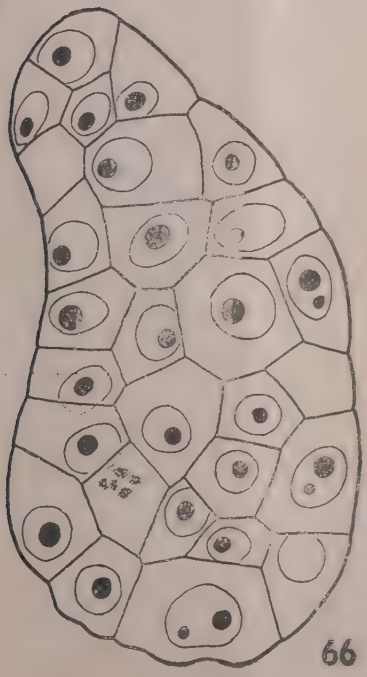

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healthy [Juliano, 1937]. We find that in *Olour*, *Cambodia*, *Higgins* and *M. odorata* the zygote[1] degenerates. Its behaviour in *Paho* could not be ascertained because of lack of proper material. Since the zygote fails to develop in *Strawberry*, *Florida No. 11*, *Olour*, *Higgins*, *Cambodia* and *M. odorata*, these cannot serve as female parents in any hybridization programme. They may, however, be useful in raising uniform stock from the adventive embryos.

The adventive embryos usually arise from the nucellar cells located in the upper part of the embryo sac[2]. Embryonic masses are formed as a result of the enlargement and division of a single cell or a group of cells located close to the embryo sac cavity. Juliano and Cuevas [1932] and Juliano [1934] record a similar condition in *Pico* and *Strawberry*. In *Carabao* [Juliano, 1937], however, the nucellar cells at the micropylar end begin disintegrating, so that the embryo sac lies directly below the epidermal cells of the nucellus. It is some of these epidermal cells which proliferate and produce the supernumerary embryos.

In some other plants, e.g. *Citrus* [Osawa, 1912] and *Opuntia* [Maheshwari and Chopra, 1955], the embryo initials arise from the micropylar end. In *Opuntia*, however, the cells along the sides may also produce adventive embryos. In *Alchemilla pastoralis* [Murbeck, 1902] and *Trillium undulatum* [Swamy, 1948] the nucellar cells at the basal end of embryo sac give rise to additional embryos.

An interesting feature of the polyembryonic forms is the variability in the number of embryonic masses, even within the same variety as is evident from the following data :

I. *Mangifera indica*			
1. *Olour*	6—14	embryos	
2. *Paho*	1—9	,,	
3. *Higgins*	3—12	,,	
4. *Cambodia*	4—9	,,	
5. Var. from Singapore	3—6	,,	
6. *Carabao* or *Pico*	10—30	,,	[Mendiola, 1926]
7. *Pico*	3—4	,,	[Juliano and Cueval, 1932]
8. *Florida No. 11*	6	,,	[Belling, 1908]
II. *Mangifera odorata*	2—8	,,	

Although the number of embryonic cells is fairly large in some varieties, that of the embryonic masses and later of the differentiated embryos becomes gradually reduced ; most probably due to competition for food materials.

In cases where the zygote invariably degenerates, all the embryos are evidently asexual in origin. But in others where the sexual embryo also develops along with the nucellar ones, it is often difficult to distinguish it from the latter. This is because of the fact that both zygotic and adventive embryos are very much alike in appearance. They are all characterized by the absence of suspensor[3]. About *Carabao*, Juliano

[1] We prefer to adopt the term zygote to egg as we presume that along with the normal endosperm development syngamy also occurs. However, actual fertilization has to be seen before one can be sure of it.

[2] Only in *Paho* we observed a few embryos arising from the middle of the ovules.

[3] In *Citrus* it is at least possible to distinguish a sexual embryo from the sporophytic ones in ear stages of development. The former possesses a definite suspensor, while the latter are devoid of it (*see* Webber & Batchelor, 1948).

[1937] writes, "Where two or more embryos which are nearly identical in size are found in an embryo sac, the difficulty of distinguishing the sexual from the asexual embryos increases, and only their relative positions can be used as a criterion by which one can differentiate one from the other. For instance, the nearer the micropylar end is in all probability the sexual embryo while those farther away are the asexual ones. This may only be true when the embryos are small, but at an advanced stage the situation is reversed." We do not consider it very safe to decide this issue from the position of the embryos. In some of our monoembryonic varieties the zygote is at the normal micropylar position, but even the two-and four-celled proembryos were seen to occupy a lateral position. If a similar situation were to arise in the polyembryonic forms, one is likely to mistake a lateral zygotic embryo for a nucellar one and a central nucellar embryo for one which is zygotic.

Another noteworthy feature in the polyembryonic forms is the varying degree of fusion exhibited by the closely packed young embryonic masses within an embryo sac. Such a condition was seen in *Olour*, *Paho* and *Cambodia* where embryos with three or more cotyledons are not too rare. Fusion often occurs in the radicular region and this results in seedlings with multiple shoots. It must be pointed out here that such a phenomenon can also result if adventitious buds arise at or before the time of germination [Arndt, 1935].

Endosperm formation is a regular feature in the varieties with nucellar embryos [*see* also Juliano, 1934, 1937]. This is quite essential as endosperm provides nourishment to the growing embryonic masses. Archibald [1939] reports that in *Opuntia aurantiaca* adventive embryos develop to maturity without the formation of endosperm tissue. This seems to be doubtful, as all the species of *Opuntia* exhibiting nucellar polyembryony show abundant free nuclear endosperm [Ganong, 1898 ; Maheshwari and Chopra, 1955].

The causes of nucellar polyembryony are not fully understood. In 1921, Haberlandt put forth a "Necrohormone Theory" as a possible explanation of adventive embryony. He pricked the ovules of *Oenothera* so as to damage the cells surrounding the embryo sac, and in one case observed two embryos arising from the nucellus. Beth [1938] carefully repeated Haberlandt's experiments, but did find support for his hypothesis. Recent workers have come to doubt the validity of Haberlandt's experiments after trying his methods on a variety of plants.

Another view is that nucellar embryony is hereditary and may be br ought about by hybridization. Leroy [1947] believes that adventive polyembryony in *Mangifera indica* is a genetic character controlled by one or more recessive genes. Fagerlind [1946] regards the stimulus initiating nucellar embryony to be of a chemical nature. He induced this in the castrated flowers of *Hosta* by the application of 1 per cent indoleacetic acid. He could not, however, stimulate the division of the primary endosperm nucleus.

Juliano [1937] states that there are no known polyembryonic varieties in India. However, some of these varieties developed the polyembryonic condition, when grown in Philippines and Florida. Juliano [1937] believes that this phenomenon

is due either to natural cross pollination between the polyembryonic mangoes of Florida and the imported Indian varieties, or to a reversion brought about by the influence of environment. He adds that if the first explanations were true, all the imported Indian mangoes should show polyembryony which, however, is not the case. Without commenting on Juliano's views, it may be stressed that some mango varieties growing under Indian conditions are also definitely polyembryonic [Sen and Mallik, 1940 ; Maheshwari *et al.*, 1955]. It would be interesting to study more fully such varieties as have been taken from India to Philippines and to see whether they show polyembryony when brought back to Indian soil.

Summary

The present account deals with the endosperm and embryo development of 19 varieties of *Mangifera indica* and one of *M. odorata*.

The endosperm is of nuclear type. Numerous free nuclei are produced and become distributed along the periphery of embryo sac. The nuclei exhibit great variation in size and shape. Large irregular nuclei are often produced as a result of fusion. Wall formation occurs quite late and proceeds from the apex downwards. The cells of the endosperm are normally uninucleate but some are multinucleate. In the latter case the nuclei often coalesce to form large multinucleolate nuclei.

Out of the 20 varieties studied, polyembryony has been observed in six, viz. *Olour, Paho, Cambodia, Higgins*, an unnamed variety from Singapore, and *M. odorata*. Some of the nucellar cells at the micropylar end become prominent due to their larger size and denser protoplasmic contents. They divide actively, crush the surrounding cells, and eventually enter the embryo sac cavity, where they continue their further development. The adventive embryos produced in this manner keep on developing for a longer period, so that it is possible to observe within a single seed very young to well organized embryos. Sometimes the embryonic masses fuse owing to their close juxtaposition and produce polycotyledonous embryos. The zygote usually degenerates. It was not possible to ascertain its fate in *Paho*.

The remaining varieties showed only a single embryo in each seed. It is of zygotic origin in *Desi, Chempattan, Colampan, Rajapir, Peter, Tiyyamamidi, Bauginapalli, Neelum, Rumani, Bangalora* and *Pairie*, but in *Mundappa, Imampasand* and *Malgoba* the exact origin still remains unsettled.

Acknowledgement

The authors express gratitude to Professor P. Maheshwari for his keen interest and help in obtaining the material for the present study. Thanks are also expressed to the Indian Council of Agriculture Research for a research grant in connection with a scheme on "Chemical Stimulation of the Ovule".

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REVIEWS

AN INTRODUCTION TO THE BOTANY OF TROPICAL CROPS

By Leslie S. Cobley, published by Longmans Green & Co., London, New York, Toronto (1956), pp. 537. Price 37*s.* 6*d.*

THERE is a general lack of suitable publications on the botany of cultivated plants which could be used or adapted as textbooks in graduate courses in tropical countries. Therefore, any addition to this field of literature should be looked upon as a welcome venture if such a book attains a satisfying standard with regard to the information it contains and is in keeping with the trends of present day botanical research and teaching. Apart from agricultural colleges where such a stress is obviously important there has been for sometime past a wholesome tendency in general botanical teaching in universities to authorise the economic aspects of plants. Judged from these points of view the book under review is eminently a commendable volume dealing with some of the common plants which are met with in cultivation in tropical countries. The book deals with various types of crops including food crops, cash crops, spices, beverages, etc. Even such crops as rubber producing plants and plants giving essential oils have not been omitted. The book includes accounts of the botanical features of important crop plants, viz. cereals, sugarcane, vegetables, fibres, oilseeds, legumes, tubers, and drug plants. Each crop is dealt with in a satisfactory manner, neither too elaborate nor too briefly but following a happy mean between these two extremes. The language is precise, effective and the style attractive. This is a very informative handbook on tropical crops and should be useful to graduates of agriculture and botany of Indian Universities. There are a large number of good illustrations which add to the value of the book. It is neatly printed and well bound and is altogether an attractive publication.—(U.N.C.)

"COMMERCIAL FERTILISERS, THEIR SOURCES AND USE"

By G. H. Callings (5th edition, 1955). McGraw-Hill Book Company, Inc.

THIS is a revised edition of a very useful book on fertilisers. It presents the principles of fertilisation, fertiliser manufacture, fertiliser practice and crop nutrition in a detailed and lucid manner. Written originally as a text-book for students of agricultural colleges, it has now grown into a reference volume. No book published, so far, can compare with it, in so far as the presentation of the material and the exposition of facts and figures are concerned. Every chapter has been brought up-to-date and the advances in the field of fertiliser technique and application, as a result of research in various allied branches, have been included.

A new chapter on the use of liquid fertilisers has been added. The chapters on " Fertilisers carrying the rarer essential elements " and " Principles underlying the use of fertilisers " have been considerably expanded. New material has been added on the use of chelated iron, manganese deficiency symptoms, the effect of molybdenum on plant growth, and the use of pesticides in mixed fertilisers. New techniques for the application of liquid as well as dry fertilisers have been described, and the use of radioactive isotopes as tracers has been briefly discussed.

A new innovation has been the introduction of the terms P. and K. to represent phosphoric acid and potash. It is not, however, clear why this method of expressing the fertiliser nutrients on the elemental basis is considered a step in the right direction. If free phosphorus pentoxide (P_2O_5) is never found as such in fertilisers, so also is elemental phosphorus (P). Both methods of expressing the analysis of phosphatic and potassic fertilisers have, however, been used side by side in this edition.

The printing and get-up of the book are excellent and leave nothing to be desired. —(J.A.D.)

CENSUS RESULTS BY COUNTRIES OF THE REPORT ON THE 1950 WORLD CENSUS OF AGRICULTURE, Vol. I

(Published By FAO Sole Distributors, Orient Longmans, Ltd.)

THE world census of agriculture 1950 has been a major task undertaken by FAO in recent years. The programme for the census was formulated by the FAO after discussion with Governments and technicians in the field ; the encouraging response which this programme received is reflected in the fact that nearly 100 countries and territories had participated in this census.

The large data collected as part of this world-wide census of agriculture and its interpretation is proposed to be published by the FAO in three separate volumes each dealing with different aspects of the census work. Volume I gives statistical material for different countries collected in terms of the census programme ; Volume II deals with the methodological aspect ; while the final Volume undertakes an analysis of the main subject.

The present publication which forms the subject of this review is a loose-leaf publication designed to make possible the addition of further census results in respect of the remaining countries. In the present material are covered 30 countries, of which relatively more important are British Borneo, Federal Republic of Germany, Gold Coast and British Togoland, Malaya, Nyasaland, Philippines, Sierra Leone, Uganda and Uruguay. The type of statistical material included, relates to holdings

and tenure land utilisation, agricultural population, agricultural employment, distribution of crop land over various crops, livestock and poultry, agricultural technology, fertilisers and soil dressings, irrigation and drainage, fragmentation, wood and fishery products. The above items constitute the main sections of the 'expanded list' included in the census programme and in this list are included some of the items which may not be of major practical importance for each individual country. Consequently, the statistics published for individual countries may or may not include information on some of the above mentioned points.

An important feature of the statistical data which would be of considerable interest to students and research workers in the field of agricultural economics relates to the distribution of relevant material according to size of holdings. This sort of classification serves to throw into bold relief the preponderating types of holdings (according to size) and would be of immense value in sociological studies. The distribution of holdings and acreage for each individual crop classified according to size of holding is another valuable feature of this work and classification of this type serves to throw light on the model type or types of holdings in respect to each crop. An indication, which these data give, is whether a particular crop is grown on large holdings or on plantation basis or whether its cultivation is confined to small scale plots. This has obvious utility in socio-economic studies pertaining to agricultural populations engaged in cultivation of individual crops.

The wealth of data which this Volume contains, augmented, as it will be in the future, by similar data for the remaining countries including India is sure to be of great value to research workers and to those entrusted with the task of policy decisions for agricultural development.

OFFICIAL METHODS OF ANALYSIS OF THE A. O. A. C.

(Published by the Association of official Agricultural Chemists, P.O. Box 540,

Benjamin Franklin Station, Washington 4, D.C. ; 8th edition, 1955.)

THIS treatise, describing standardised analytical procedures to applicable agricultural products and materials essential to agriculture, is well known to Agricultural Chemists all over the world and needs no introduction. In the eighth edition, usual care has been taken to present only those methods which have been demonstrated as capable of giving accurate and reproducible results in the hands of qualified chemists and to include illustrations and useful reference tables greatly adding to its value. Among its distinctive features may be mentioned the deletion of a number of methods which have become out of date in the light of recent researches and given place to modern improved procedure as also the inclusion of simplified

methods resulting from recent developments in instrumental technique. Notable under the category of deletions are the hitherto permissible alternative catalysts in the kjeldahl method for Nitrogen (only mercury being prescribed); classical methods for Vanillin, Coumarin and coal tar colours in food (now replaced by combined chromatographic spectrophotometric techniques); micro-biological procedure for examination of sugar and canned vegetables and fermentation method for thiamine which has become obsolete with the development of a fluorometric method. Additions are many, most important among these being a chapter on spectrographic methods (including flame photometric methods for the determination of Sodium and potassium in plants); field determination of radioactive contamination in Civil Defence; determination of optical—crystallographic properties; new chemical methods covering a variety of items, including a wet digestive method for potash in fertilisers, determination of L-amylase in starch and digestion in drugs; a new section on hormones providing certain chemical alternatives to bioassay methods; an expanded chapter on micro-chemical analysis covering several elements not dealt with in earlier editions and recent instrumental technique in the field of chromatography. Notwithstanding these important additions, the convenient size of the work has been maintained. Equally useful for research and professional chemists, the treatise remains unique in the field of analytical chemistry.— (K. L. K.)

"HANDLING FOREST TREE SEED"

(F. A. O. Publication March '55)

THIS is one of the useful 'Forestry Development Papers' published by the FAO to spread the knowledge of forest tree planting in all its aspects. The technical features of seed procurement for expanding tree-planting programmes are adequately dealt with. The importance of proper attention to such considerations as seed collecting, extracting, cleaning, testing, storing and packaging for transport, cannot be over-emphasised, if the seed is desired to serve satisfactorily and the loss of valuable growing seasons is to be avoided. Various practical arrangements also become necessary when effecting international seed exchanges between various co-operating countries.

The numerous points that must receive careful attention in practice are clearly elaborated in respect of satisfactory supplies of seed, especially with reference to moisture and temperature conditions in storaging and seed testing for purity, viability, genuineness and freedom from insect damages, etc.

In part II, extracts are furnished from the International rules for seed testing which have been in force all over the world since July 1, 1954. While the tests are meant primarily for determining the value of the seed for raising trees, they help to avoid the hazards otherwise inevitable to large scale crop introduction in new

regions. The necessity for standard procedure for such tests all over the world is emphasised and the details of such procedure are enumerated. Specimens of internationally accepted forms for certificates on seed testing are furnished.

Naturally, part I of the publication deals with the principles involved in the handling of tree seeds, from collection off the trees to making the seed ready for sowing. In the hands of a technically qualified Forester or Seedsman it should prove a very valuable guide for drawing up specific instructions for collectors in respect of individual species. The publication is characterised by brevity, clarity and precision and is worth being possessed by every technical Forester and professional [Seedsman. —C. A. R. B.]

DISEASES OF FIELD CROPS

By James G. Dickson

(Published by McGraw Hill Book Company, Inc.,

New York, Toronto, London. 2nd Ed. (1956.) pp. 1-517, price $ 8·50)

THIS is a second edition of a well known book on Diseases of Field Crops. The book maintains the standard of McGraw Hill publications in agricultural sciences and deals with diseases of important agricultural crops including food crops, forage and commercial crops which are cultivated throughout the world. Symptoms and descriptions of the diseases have been given crop-wise and the effect on the yield as also control measures are also indicated. In each category of crops a fairly exhaustive bibliography has been given which would be helpful to those who would like to refer to original source, for obtaining further information. Diseases of the following crops among cereals and grasses have been dealt with—barley, corn, millet, rice, rye, sorghums, sugarcane, wheat and grass. Among leguminous crops diseases of alfalfa, sweetclover, clover, soya bean, peanut, etc., have been included and among the fibre and economic crops of cotton, tobacco and flax. There are two appendices. The first contains diseases of field crops arranged according to the

casual factors, and the second bacterial and fungal parasites of field crops. There is a detailed index helpful to the reader. The book is a handy publication with copious illustrations. The binding and get up are excellent. It will certainly be useful to all interested in the diseases of agricultural crops.—(U. N. C.)

THE WHEAT INDUSTRY IN AUSTRALIA

By A. R. CHALLAGHAN AND A. J. MILLINGTON

(Publishers : Robertson

and Angus, Sydney, London, etc. 1956, pp. 1-486, price 63 S.)

THIS book deals with variousaspects of wheat farming in Australia. It also deals with the technological marketing problems connected with wheat. Compared to other countries, wheat farming in Australia may be looked upon as almost a new venture. The experience gained in growing wheat in other regions of the world were certainly fruitful in developing wheat farming in Australia. But naturally many of the practices adopted in other regions might possibly have been modified and new techniques developed. This is natural since every region has its peculiar agro-climatic complexes and cropping practices have to be adjusted to such conditional variations. Wheat growing in Australia has been very efficient and the country occupies a prominent place in the wheat map of the world. Naturally, therefore, an account of the various conditions and problems of wheat growing in Australia should form a very valuable addition to the scientific literature dealing with wheat growing. There are 25 chapters in the book on various aspects of wheat growing. It contains *inter alia* information on such important subjects as soil structure, soil nitrogen, phosphate deficiency, dry farming, diseases of wheat and their control. Even bulk-handling of wheat in Australia and its contribution to the wheat trade have been adequately dealt with. The economics of wheat production and its marketing in Australia have been stressed. In addition there is a bibliography which lists literature from where information has been culled and an index very helpful to the readers. There are a large number of illustrations which add to the

value of the book. The book has been written in a direct manner, in simple and effective English. To the credit of the authors it must be said that they have been eminently successful in dealing with the subject matter in an elaborate and exhaustive manner. It is informative and would undoubtedly be valuable to wheat growers and others interested in wheat not only in Australia but in other parts of the world as well.—(U. N. C.)

AGRICULTURE IN WORLD ECONOMY

(Published by Food and Agricultural Organization of the United Nations, Rome, Italy, 1955, pp. 1-76, Price $ 1·00 or 5*s*.)

THE Food and Agriculture Organisation is an international organisation which deals with the problems of food and agriculture in the world. As such, this organisation is in a position to bring out publications dealing with agriculture in its international set-up. Agriculture is ' the world's largest primary industry ' and, therefore, it affects the economy of the world at large.

This booklet entitled " Agriculture in the World Economy " has been brought out by the F.A.O. in order to demonstrate the importance of agriculture in the world's economy. There has been generally a poor realisation of the fact that agriculture is a world problem and, therefore, its status and progress are of vital concern to all human beings.

The present book is a general survey indicating certain trends in the present time. After a few pages of introductory remarks there is a chapter devoted to the activities of international organisations directed to achieve freedom from want. The world trends in production, population and income, purchasing power, labour, land and capital are all dealt with briefly and in a simple manner. This is, as the conclusion says, a bird's eye view of agriculture as the oldest and the most important of all primary industries for the satisfaction of our vital needs. There is thus a necessity of expanding agricultural production to meet the demands of increasing population. —(U. N. C.)

FORESTRY

By T. A. Robbie

(Teach Yourself books ; Published by English Universities Press Ltd., London. Price : Sh. 6 net.)

This handy publication is apparently meant primarily for the guidance of those engaged in or interested in forestry in the United Kingdom and similar temperate countries, as all the examples and references are to species of plants and

trees and practices in vogue, in that country. However, there is much information of general forestry interest and practical applicability which can be adapted for local guidance elsewhere also.

The publication gives brief particulars of the growth and structure of trees, seed procurement and nursery work, planting practices and tending methods. It also deals with measurements of timber, trees and woods and protection, management and utilisation methods in an elementary way.

The book is well illustrated with numerous line drawings and sketches which are very informative and instructive.—(C. A. R. B.)

THE STORAGE OF SEEDS FOR MAINTENANCE OF VIABILITY

By E. Biasutti Owen

(Published by the Commonwealth Agricultural Bureau)

THIS is a small handsomely bound and neatly printed bulletin. It contains review of literature dealing with storage of small quantities of seeds without loss of viability. Information has been given on the longevity of seeds of field crops, pasture crops and horticultural crops. The factors affecting their viability have also been dealt with. Such subjects as changes in respiration and chemical composition of seeds, conditions suitable for growth of fungi, dormancy, seed treatment, etc., during storage have been discussed. The publication consists of ten chapters with following headings :—Introduction ; the longevity of seeds ; factors affecting the viability of seeds in storage ; relationship between the relative humidity of the atmosphere and the equilibrium moisture content of seeds ; drying seed for storage ; materials and methods for drying storing seeds ; changes accompanying the loss of viability of seeds ; dormancy and hard seededness in relation to storage ; seed treatment in relation to storage ; genetical aspects of seed storage ; and longevity and storage of seeds of particular plants.

In addition there is a conclusion and an appendix containing information on viability of seeds after storage for different periods and under different conditions. There is a fairly exhaustive bibliography and also an index which will be useful for reference work.

The problem of seed storage is a complex one but it has been dealt with adequately, though briefly. The book will be helpful to scientists, plant physiologists, students of agriculture, etc.—(U. N. C.)

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Instructions to Authors

Articles intended for *The Indian Journal of Veterinary Science and Animal Husbandry* should be accompained by short popular abstracts of about 300 words each.

In the case of Botanical and Zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References of literature, arranged alphabetically according to authors' names, should be placed at the end of the articles, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the articles, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets. When the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state 'original not seen'. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized, the size adopted being crown-quarto (about 7 in. $\times 9\frac{5}{8}$ in. cut), no text figure when printed should exceed $4\frac{1}{2}$ in. $\times 5$ in. Figures for plates should be so planned as to fill a crown-quarto page, the maximum space available for figures being $5\frac{1}{4}$ in. $\times 8$ in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.

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